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Studies in Avonian Brachiopoda: II. The Genus *Camarophoria.*

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I. INTRODUCTION.

THE genus *Camarophoria* was established by King in 1846 [1] for certain Permian brachiopods bearing internal structures similar to those of the Pentamerids. The essential features were the presence in the ventral valve of a spondylium ("an arch-shaped process") supported by a median septum ("medio-longitudinal plate"). "The arch-shaped process and its supporting or suspending plate correspond in every respect except in degree with the apophysary system belonging to the large valve of *Pentamerus.*" [2] In the dorsal valve there is developed a high median septum supporting a well-developed spondylium ("spatula-shaped process").

The type of the genus is a Permian form, *Terebratula Schlotheimi*, von Buch, but a few species have been found in Carboniferous strata. Amongst these, *Camarophoria crumena* (Martin) has for long been recognized as being similar to, if not identical with, *Camarophoria Schlotheimi*. At first, Davidson considered them to be distinct species,[3] but later remarked [4] " . . . I became convinced that not only were the Carboniferous specimens . . . specifically identical with the Permian *Camarophoria*, but that it was impossible to distinguish the last from *A. crumena* of Martin". Later, Davidson said that "None of the Carboniferous specimens showed perfectly the interior arrangement", although some of the internal features "could be distinctly seen in several examples".[5] Recently the writer has obtained casts of *Camarophoria* from the Upper Limestone Shales (D_{2-3} Zone) of Gower,[1] and in view of this lack of evidence as regards the internal features of the Carboniferous forms, a description of these, which exhibit beautifully the internal structures, may be useful.

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[1] W. King, *Ann. Mag. Nat. Hist.*, xviii, 1846, p. 28.
[2] W. King, "Permian Fossils of England": *Pal. Soc.*, 1850, p. 114.
[3] T. Davidson, *British Fossil Brachiopoda*, ii, 1858, p. 25.
[4] Ibid., p. 114.
[5] Ibid., p. 115.

II. Description of the Specimens from Gower.

1. *External Features.*—Complete specimens showing the details of the exterior have not been found, but the following description is derived from an examination of several specimens.

The Gower forms are, for the most part, more or less triangular in outline, with the widest portion of the shell much nearer the anterior than the posterior border. The dimensions are usually about as follows: length, 16 mm.; proportion of breadth to length, about 1·24 : 1. The relative depth naturally varies to a great extent, as increase in depth, in adult specimens, is practically unaccompanied by any increase in length. The lateral expansions, so common a feature in some of the Permian species of this genus,[2] have not been observed in the Gower specimens, possibly owing to the mode of preservation.

In young specimens, and in the immature stages of adults, there is no sign of any mesial elevation in the dorsal valve (with corresponding sulcus in the ventral), and the valves are evenly rounded. In adult forms, however, there is developed at a distance of about a third of the length of the shell from the beak, a more or less prominent mesial fold and sulcus, so that the margin becomes markedly uniplicate, or sometimes sulciplicate. Generally, though there is considerable variation, the mesial fold is fairly well marked off from the lateral slopes.

Costation, in the great majority of specimens, is only developed on the anterior portion of the valves, and the ribs rarely extend for more than half the distance between the anterior border and the umbo. Together with the variation in the length of the ribs, there is also variation in their degree of prominence and in their shape. Generally ribs are more or less well marked near the anterior border, and no specimens have been found comparable with some of the Permian forms figured by King, on which ribs are completely absent from the flanks. In the majority of forms the ribs are rather less acutely rounded than appears to be usually the case in specimens of *Camarophoria crumena.* The ribs bordering the sulcus, one on each side, in the ventral valve, are generally larger and more pronounced than the other ribs; this phenomenon is exhibited to a slight extent by some of the Permian forms figured by King, but it is not so general nor so marked as in the Gower specimens. Multiplicate forms such as *C. humbletonensis* Howse,

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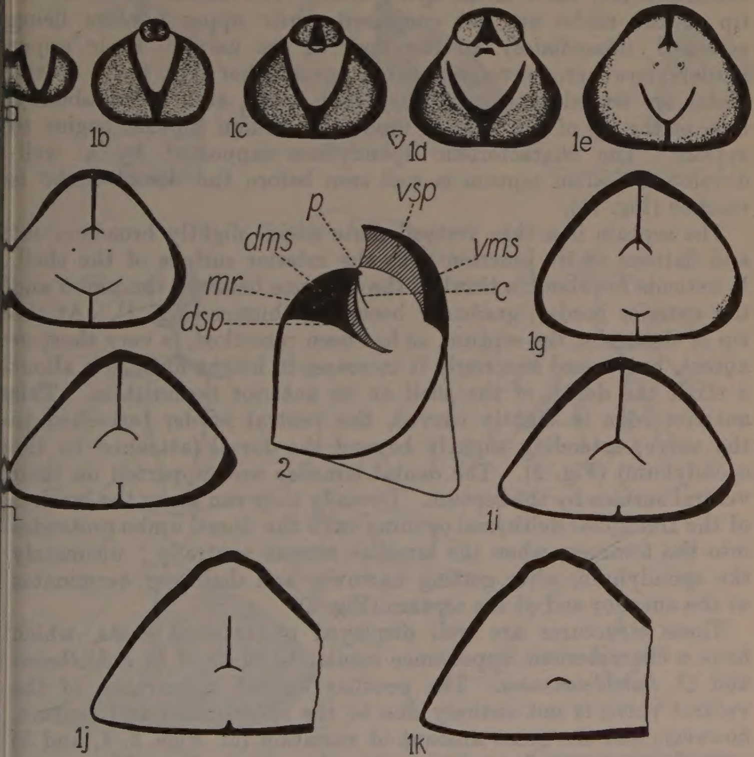
[1] For notes on these beds see Part I: Geol. Mag., 1927, p. 116.

[2] See, e.g., Davidson, op. cit., pl. ii, figs. 9 and 27.

C. *multiplicata* King) have not been found in Gower. The mesial old of the dorsal valve is generally triplicate, the median rib being levated to some extent above its neighbours. Correspondingly here are normally two ribs of equal size in the ventral sulcus.



IGS. 1*a*–*k*.—Serial sections through the shell of *Camarophoria* cf. *crumena* from Gower, showing the structure and development of the various processes. × 2. Fig. 1*a* is a section at a distance of approximately 1 mm. from the tip of the ventral umbo ; Fig. 1*b* at a distance of 3 mm. ; the remaining sections at distances of about ·5 mm. apart, except Fig. 1*k*, which is ·3 mm. from Fig. 1*j*.

IG. 2.—Reconstruction of the internal structure of *Camarophoria* cf. *crumena* based on the serial sections of Fig. 1, showing, in the ventral valve, the median septum (*vms*) supporting the spondylium (*vsp*), and in the dorsal valve the crura (*c*), the cardinal process (*p*), the median septum (*dms*) supporting the spondylium (*dsp*) with its median ridge (*mr*). × 2.

he flat-topped fold with several ribs of equal size, which is often een amongst Permian forms, has not been recognized.

The ventral umbo in the specimens described seems to be rather more elongate and acute than is usually the case in typical specimens of *C. crumena* or of *C. Schlotheimi*. In no instance has either a pseudodeltidium or a deltidium been seen, and in all the forms examined the umbo of the dorsal valve protrudes into the delthyrial opening. King also observed the last phenomenon.

2. *Internal Features.*—(i) Ventral Valve.—The most outstanding feature of this valve is the spondylium. The dental plates at the tip of the umbo are not conjoined, their upper borders being attached immediately to the floor of the valve. Their upper borders, however, converge towards one another (Fig. 1*a*). As the plates are traced anteriorly, they soon unite, and within about a mm. of the tip of the ventral umbo the median septum begins to appear. The characteristic spondylium supported by a well-developed median septum is well seen before the dorsal umbo is reached (Fig. 1*b*).

The septum is a thin vertical plate which slightly broadens out and flattens at its junction with the interior surface of the shell. It extends for about a third of the distance between the umbo and the anterior border, gradually becoming thinner (Fig. 1). At the tip of the umbo, the septum, as has been remarked, is very short or absent, but traced anteriorly it increases in height until it is about a sixth the depth of the shell at its anterior termination. This anterior edge is slightly curved, the ventral border (attached to the valve) extending slightly beyond the dorsal (attached to the spondylium) (Fig. 2). The dental lamellae are supported on their ventral surface by the septum. Dorsally they run along the borders of the triangular delthyrial opening until the dorsal umbo protrudes into the foramen, when the lamellae retreat ventrally ; ultimately the spondylium, after getting narrower and shallower, terminates at the anterior end of the septum (Fig. 2).

These structures are well displayed on internal casts, which have a characteristic appearance similar to those of *C. Schlotheimi* and *C. humbletonensis*. The peculiar beaked appearance of the ventral valve is not entirely due to the spondylium and septum, however, and the great amount of variation (cf. Figs. 3, 4, and 5) is for the most part due to a secondary deposit of callus. This occurs above the spondylium, between that structure and the inner surface of the valve. It may partially or completely fill the intervening cavity, and hence give rise to the variations observed. Owing to this callus the appearance of the casts frequently suggests that the septum is quite a short structure which only exists along the anterior portion of the spondylium, the posterior part of which rests directly on the valve. Actually, as the serial sections show (Figs. 1*a* and 1*b*), this is not the case, the septum being well developed quite near the tip of the umbo. Presumably a similar state of affairs existed amongst the Permian forms of *Camarophoria*.

In no specimen examined are the vascular sinuses well displayed ; all the components of the system have not been found. It appears, however (Figs. 7 and 8), that the vascular system is very similar to that of *C. humbletonensis*.[1] In the ventral valve there are two main trunks which branch off from the anterior end of the median septum. In several specimens the septum extends slightly beyond the point of branching. In the immediate vicinity of the septum the sinuses are sunk in definite hollows (on the cast). The nearly complete circles seen in some of the Permian species on the posterior lateral portions of the valves have not been observed in the forms described, but the small portions of the main trunks preserved

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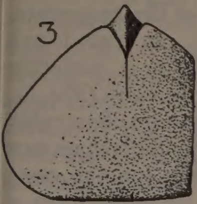
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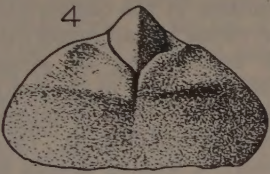
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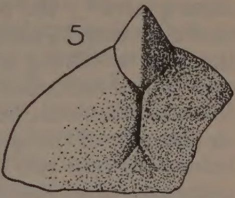
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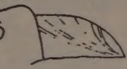
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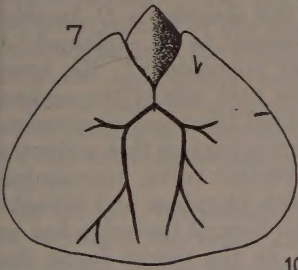
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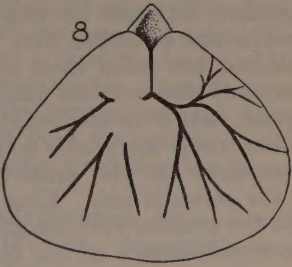
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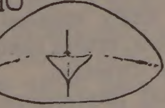
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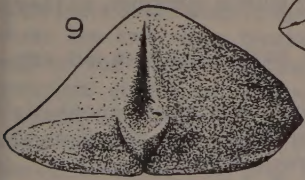
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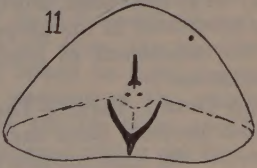

FIGS. 3–5.—Casts of ventral valves of *Camarophoria* cf. *crumena* from Gower, showing variation. × 2.

FIG. 6.—Cast of the spondylium of the ventral valve of *Camarophoria* cf. *crumena* from Gower, showing striations. × 4.

FIGS. 7, 8.—Diagrammatic representation of the vascular sinuses in the ventral and dorsal valves respectively of *Camarophoria* cf. *crumena* from Gower, synthesized from several specimens. × 2.

FIGS. 9–11.—Umbonal views of species of *Camarophoria*. Fig. 9, *C.* cf. *crumena* from Gower; × 2. Fig. 10, *C. Schlotheimi* from Humbleton; × 2. Fig. 11, *C. humbletonensis* from Humbleton; × 1.

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[1] Davidson, op. cit., pl. ii, fig. 13; King, op. cit., pl. viii, fig. 7.

suggest that they were present. Only the central portion of the system has been well seen, and this consists of two branches extending to and converging slightly towards the anterior border. They, in their course, give off minor branches.

No muscle impressions have been observed on the surface of the casts in any way analogous to the striated scars seen in many other genera [1]; the condition of the casts precludes the suggestion that they may be absent owing to bad preservation. In some forms the area overlying and surrounding the spondylium is perfectly smooth and continues the even curve of the rest of the valve (Fig. 3). In other specimens, however, well-defined impressions are observable on each side of the median septum (Fig. 4). On each flank these can be divided into two areas: a smaller deeply sunken (on the cast) triangular area, which is separated by a raised shoulder from a larger and more or less quadrangular area anterior to it, which is again marked off from the rest of the shell by a prominent transverse shoulder. Davidson likewise recognized this shoulder in *C. humbletonensis* and remarked that "it still remained to be explained".[2] Davidson has called these areas muscular impressions.[3] He, however, only observed one undivided area on each side of the median septum, which he attributed to the cardinal (divaricator) muscles. If these really are muscle scars, the two areas suggest that adductor impressions are also preserved on the ventral valve, represented by the posterior pair. King disagreed with Davidson and thought that the muscles were not attached to the floor of the valve but to the dorsal surface of the spondylium.[4] In the Gower forms the spondylium is frequently finely striated (Fig. 6); the striations may be growth lines, however, rather than muscle markings, as they are orientated in the proper direction.

No indications of genital impressions have been seen on any specimens.

(ii) Dorsal Valve.—The cardinal process is a small apophysis which projects from the tip of the dorsal umbo into the visceral cavity. Its inner surface appears to be crenulated or striated.

The crura are two fine processes attached to the hinge plate just anterior to the cardinal boss. They are little more than 1 or 2 mm. long, unless, as may be the case, they are broken in the specimens examined (Fig. 2).

There are no crural plates supporting the crura, but just beneath the latter there is developed what Davidson and King have called a "spatula-shaped process", supported by a median septum. A similar structure has been termed a cruralium amongst the pentamerids, where it is formed by the convergence and fusion of the crural plates along their dorsal edges. In *Camarophoria*, however, the crura are quite distinct and separate from this process. Moreover, the latter is formed as an outgrowth from the median septum, which is the first part of the structure to appear (Figs. 1*b*, *c* and *d*). It therefore seems advisable to avoid the use of the term " cruralium " for the structure in this genus, and in this paper the term " dorsal spondylium " will be employed. At the tip of the umbo the median ridge exists as a plate extending from the outer to the inner surface. Traced anteriorly, its inner portion increases in width and the cross section becomes triangular. At the same time the central portion of the broad inner border of the septum becomes separated from the wings by slight hollows ; the inner border, in other words, becomes forked (Figs. 1*d* and *e*). The septum becomes less massive and increases in height ; the two flanks of the incipient spondylium elongate laterally, becoming curved into the typical " spatula-shaped process " ; and the median ridge on the spondylium (really the inner portion of the median septum) increases in height. The structure extends for a distance of about a third the length of the shell, the spondylium possessing a considerable upward curve, so that its anterior extremity is nearer the ventral than the dorsal valve. Before this extremity is reached both the median septum and the ridge have disappeared, the latter preceding the former (Fig. 2).

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[1] See, e.g., George, op. cit., figs. 3–9.

[2] Op. cit., pl. ii, fig. 12.

[3] Op. cit., pl. ii, figs. 11 and 23; "Notes sur les Genres *Athyris, Camarophoria, Orthisina,* et *Strophalosia*": *Bull. Soc. Linn. Norm,* 1857, p. 17.

[4] Op. cit., p. 115.

On the cast, the posterior portion of the structure, together with the cavities of the crura, are well seen (Fig. 9). Apparently very little, if any, callus was deposited in this valve.

The vascular sinuses seen in this valve have been made out in a little more detail than in the ventral valve. As in *C. humbletonensis*, there are two main trunks which branch off from the anterior end of the median septum ; these swing round to form nearly complete circles on the posterior lateral portions of the valve. Various dichotomozing branches are given off by these trunks and their two slightly convergent main branches which run down the centre of the shell (Fig. 8).

No indications of either muscular or genital impressions have been observed on this valve.

III. COMPARISON WITH OTHER SPECIES.

Camarophoria crumena (Martin).—Vaughan[1] recognized that the Gower specimens were not identical with the holotype as figured by Martin,[2] and gave them the name of *C.* cf. *crumena* Davidson (*non* Martin). The forms described certainly differ considerably from Martin's figure, and approach more closely to some of

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[1] E. E. L. Dixon and A. Vaughan, " The Carboniferous Succession in Gower " : *Q.J.G.S.*, lxvii, 1911, p. 550.

[2] W. Martin, *Petrifacta Derbiensia*, 1809, pl. xxxvi, fig. 4.

Davidson's specimens. They differ from the latter chiefly in the following characteristics: (i) They are, generally speaking, rather more triangular than rhomboidal. (ii) The ribs bounding the mesial sulcus in the ventral valve are larger and more pronounced than the others. Probably Vaughan's designation of *C.* cf. *crumena* would be the most appropriate.

Camarophoria Schlotheimi (von Buch).—This species was considered by Davidson to be synonymous with *C. crumena*; but von Buch's figure[1] is quite different from typical forms of *C. crumena*, particularly in the large number, extent, and angularity of the ribs, and in the character of the mesial fold. Davidson's figures of *C. Schlotheimi* represent specimens similar to those of von Buch in the character of the ribbing, but much larger and not so elongate or quadrangular in shape. Some of the specimens figured by King approach more closely to those of von Buch.

Generally, apart from the great amount of variation, *C. Schlotheimi* appears to be a smaller form than *C. crumena*, and also to be of different shape. The beak is much less prominent than in the latter form.

Internally, differences are rather more marked. The median septum which supports the spondylium in the ventral valve does not appear until about a quarter of the length of the spondylium is reached, and the septum is relatively much lower. The dorsal septum is usually much shorter in *C. Schlotheimi* than in *C.* cf. *crumena*,[2] and in nearly all the cases examined the angle of divergence of the lateral portions of the spondylium in this valve is much more acute than in *C.* cf. *crumena* (Figs. 9 and 10). Occasionally, in some specimens of *C. Schlotheimi* the median ridge on the dorsal spondylium is absent.

In a specimen of *C. Schlotheimi* from Humbleton, preserved in the Sedgwick Museum, the cast shows the area surrounding the ventral median septum to be obliquely corrugated. This appears to confirm Davidson's suggestion that the muscles were attached to the valve in this region.

Camarophoria humbletonensis Howse.—This species, although differing from the previous forms in size, shape, and costation, is evidently of the same group, and it is interesting to compare the internal characters.

In the ventral valve, as King[3] has shown in his reconstruction, the median septum which supports the spondylium in the ventral valve does not appear until about a half the length of the spondylium is reached. The latter is thus directly attached to the floor of the valve for a greater distance than is the case either in *C. Schlotheimi* or in *C.* cf. *crumena*.

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[1] L. von Buch, *Über Terebrateln*, 1834, Tab. ii, fig. 34.

[2] Compare Fig. 2 with Davidson, *Brit. Foss. Brach.*, ii, pl. ii, fig. 27.

[3] Op. cit., pl. viii, fig. 4.

The median septum of the dorsal valve is, relatively, further decreased in length.

All the structures appear to be more massive than in the preceding forms; the dorsal spondylium appears to be particularly stout, but its median ridge is relatively slender (Fig. 11).

In conclusion, the writer wishes to express his thanks to Dr. A. E. Trueman, F.G.S., and to Mr. Henry Woods, F.R.S., for their kindness in reading over the manuscript and making several suggestions.

The Carlisle Basin.

By E. E. L. Dixon, B.Sc., F.G.S., and F. M. Trotter, M.Sc., F.G.S.

PROFESSOR GREGORY'S kindly review of the Carlisle memoir [1] raises once more the vexed question of the structure of the New Red rocks of that district. Two borings, one at Abbey Town and the other at Bowness, prove a thick series of variegated shales in the drift-covered western part of the area. A third boring proved red beds beneath the Lias at Great Orton. As Professor Gregory points out, the correlation of these red beds with the Abbey Town shales is uncertain. Though expressing the same caution, he had nevertheless previously adopted the correlation,[2] his section through Great Orton, here reproduced, showing the beds at the two places as continuous. In what follows it will be easy to distinguish the evidence relating to Great Orton from that dealing specifically with the Abbey Town shales.

We agree with him as to the sequence, but as regards the position of the Abbey Town shales in this sequence three views have been put forward, which are contrasted below, the group correlated with the shales in the bore being indicated by an asterisk. We are in agreement with Goodchild and Aveline.

HOLMES.	GOODCHILD & AVELINE.	GREGORY.
Stanwix Shales.	*Stanwix Shales.	Stanwix Shales.
Kirklinton Sandstone.	Kirklinton Sandstone.	Kirklinton Sandstone.
*Upper Gypseous Shales.		
St. Bees Sandstone.	St. Bees Sandstone.	St. Bees Sandstone.
St. Bees Shales.[3]	St. Bees Shales.[3]	*St. Bees Shales.[3]
Penrith Sandstone.	Penrith Sandstone.	Penrith Sandstone.

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[1] "The Carlisle Basin": GEOL. MAG., 1926, pp. 377–9.

[2] "The Solway Basin and its Permo-Triassic Sequence": GEOL. MAG., 1915, pp. 241–9.

[3] For the sake of clarity this group is given the name by which it is known in the recently published memoir. Holmes called them Lower Gypseous Shales, and other writers, including Professor Gregory, have referred to them as Gypseous Shales.

It will be seen that Holmes has an "Upper Gypseous Shales" between the Kirklinton and the St. Bees Sandstones. The re-survey of the area has shown that, as Professor Gregory has found elsewhere, these two sandstone-groups are conformable and pass insensibly from one to the other. Hence Holmes' group must be rejected, and the issue is narrowed to one between Professor Gregory's and Goodchild and Aveline's views. Whereas Professor Gregory believes the Abbey Town shales to be St. Bees Shales (Upper Permian Marls so-called), we regard them as Stanwix Shales (Keuper Marls).

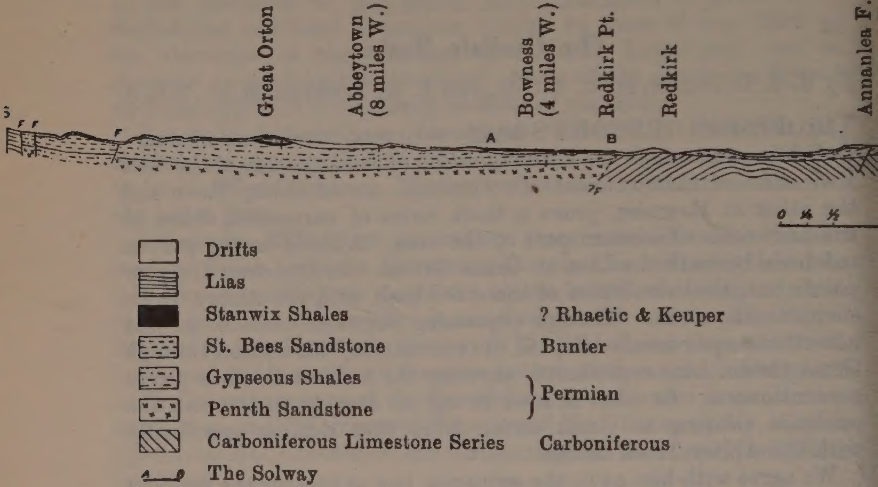

FIG. 1.—Section across the Solway Firth (A–B) and the Carlisle Basin (Prof. Gregory's interpretation). Reproduced from GEOL. MAG., 1915, p. 244, Fig 1. (The original figure which is on a larger scale should be consulted.)

Two widely divergent conceptions of the structure of the area result. Professor Gregory's theory, which is developed in the 1915 paper cited above, is illustrated by Fig. 1 from that paper; the usually-accepted view, to which we adhere, is shown on the map (Fig. 2), reproduced from the recent memoir.

We will first deal with the stratigraphical evidence, as it is by far the most important.

Before the re-survey, Stanwix Shales, though surmised to exist south of the Lias outlier, had not been proved there. During its progress they were found and their base traced along the River Caldew, north-east of Dalston. Their significance in this position is two-fold. In the first place they are completely out of line with the outcrop north-east of the Lias, and their presence thus confirms the existence of a large fault bounding the Lias on the north-east.

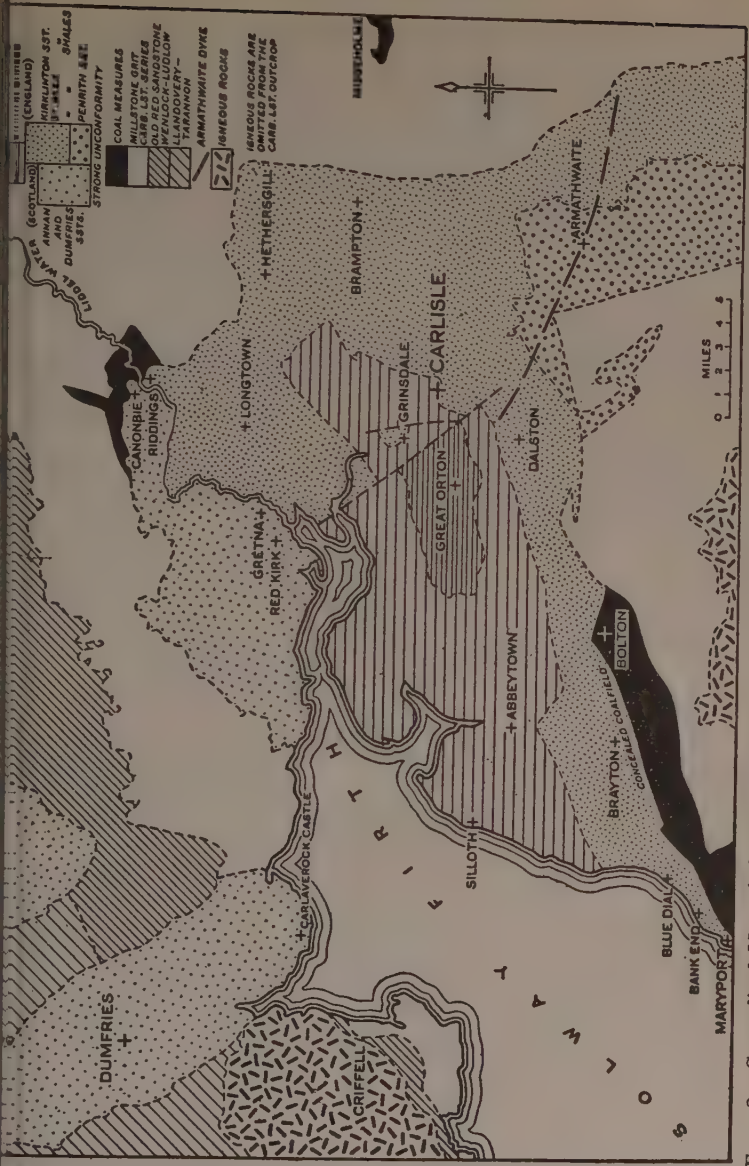

Fig. 2.—Generalized Map of the Solway Basin. Reproduced by permission of the Controller of H.M. Stationery Office from *The Geology of the Carlisle, Longtown and Silloth District*, fig. 2.

This is the Cummersdale fault of the memoir, or the Grinsdale ault of Professor Gregory, which he regards as doubtful and unimportant. In the second place the fact that they underlie the Lias hereabouts with a thickness of some 1,000 ft., and are underlain in turn by a still greater thickness of Kirklinton and St. Bees Sandstones before the St. Bees Shales are reached, brings into relief the difficulty of accepting Professor Gregory's correlation of the beds beneath the Lias at the bottom of the Great Orton bore, close by, with the St. Bees Shales. Not only is a great hiatus within the New Red Sandstone-Lias sequence postulated by such a correlation, but also the hiatus would be in close proximity to a complete series in which it is represented by over 2,000 feet of strata. In such close proximity, in fact, that it would be necessary to separate it from the complete series by the "Dalston fault". Hence the importance of the latter "fault" to Professor Gregory's hypothesis, but the evidence for it, deduced by him from the little we know of the andesite dyke in the drift-covered Carlisle district, is valueless. As there is no evidence for the "Dalston fault", apart from the theoretical consideration based on the supposed existence of St. Bees Shales in the Great Orton bore, we reject it.

The difficulty attaching to the hypothesis that St. Bees Shales closely underlie the Lias outlier at Great Orton is also apparent when we consider that the outlier is known to be ringed around, beyond an intervening shale outcrop, on all sides except where the Solway Firth hides the "solid" rocks by the outcrop of the thick Kirklinton-St. Bees Sandstone. The hypothesis demands the complete disappearance of this sandstone within the ring at a distance of little more than 2 miles from the nearest outcrop on the ring.

Let us now turn to the lithological evidence of the age of the Abbey Town shales.

Some sandstones proved beneath them in the boring were likened by Holmes, who saw the material, to an outcrop now known to be Kirklinton Sandstone. From their available description they are at least as likely to belong to that group as to the Penrith Sandstone with which Professor Gregory correlates them.

In thickness the Abbey Town shales are closely comparable with the Stanwix Shales in the full development south of the Lias outlier, but considerably exceed the St. Bees Shales.

In being variegated the Abbey Town shales resemble the Stanwix Shales and differ from the St. Bees shales, *which are red throughout.* This marked difference from the St. Bees Shales has not been noticed by Professor Gregory, who lays weight on the difference between the colours of Stanwix Shales seen weathered at the surface and those ascribed to the Abbey Town shales by borers.

In containing gypsum the Abbey Town shales certainly resemble the St. Bees Shales, not the Stanwix Shales, but the latter are known only at their outcrop, where, like many gypseous formations, they may have lost gypsum by weathering. The Stanwix Shales may owe their apparently greater marliness to the same cause.

The Abbey Town shales differ from both the other groups in containing a little salt, a difference which is more significant in the case of the St. Bees Shales than in that of the Stanwix group, as the former have been penetrated in an unweathered state by several Cumberland borings.

Finally it may be mentioned that marls of the same age as the Stanwix Shales contain both salt and gypsum in the Isle of Man. They are underlain by a great mass of sandstone which, Professor Gregory has shown,[1] includes the Kirklinton as well as the St. Bees group, and their general stratigraphical equivalence to the Stanwix Shales, with which they are of comparable thickness, is therefore beyond question. It should be added that he distinguishes them from the Abbey Town shales, partly because their salt and gypsum are in markedly different proportions, and partly on account of their description as recorded by borers. Again, however, we prefer to group the Abbey Town shales with these Keuper shales, as both groups contain salt and gypsum and both are variegated, rather than with the St. Bees Shales, which contain no salt and are red throughout.

The Glacial Drifts of Western Cardiganshire.

By Kenneth E. Williams, B.Sc., University College of Wales,
Aberystwyth.

(PLATES VIII AND IX.)

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I. Introduction and History of Previous Research.
II. Distribution and Description of the Drifts.
III. Summary and Conclusions.

I. Introduction.

The district dealt with in this paper includes the coastal region of Cardiganshire, and that part of the county which lies to the south-west of a line drawn from Aberporth on the coast to Newcastle Emlyn in the Teifi valley.

The coast of Cardiganshire sweeps in a curve from south-west to north-east for nearly 50 miles, so that Upper Borth in the north of the county is about 28 miles east of Gwbert in the south. (See Fig. 1.)

It is known that the drifts in the south of the county are the product of the ice-sheet which occupied and moved down the Irish Sea during the Glacial Period, whilst those in the north of the county are the product of the local Welsh ice. The purpose of this paper is to give a connected description of the deposits, mainly of the coastal region, and to attempt to show the relationships which existed, during the Glacial Period, between the local Welsh ice and the Irish Sea ice-sheet.

History of Previous Research.—The glacial drifts of this region have been almost entirely neglected in the past, and the literature concerning them is, therefore, very scanty. So far as the writer is aware, previous descriptions have been restricted to those deposits which occur in the northern and southern extremities of the county.

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[1] "The Red Rocks of a deep Bore at the North End of the Isle of Man," *Trans. Inst. Min. Eng.*, vol. lix, 1920, pp. 156–68.

Professor W. Keeping has described the deposits in the neighbourhood of Aberystwyth (5 and 6)[1] and in his later paper made some observations on the glaciation of Central Wales in general. In this paper he refers to the glacial clay which occurs in the southern part of the county and recognizes that it is different from that found in the neighbourhood of Aberystwyth. He describes this clay (around Cardigan) as " a stiff, unctuous clay, . . . of a purplish

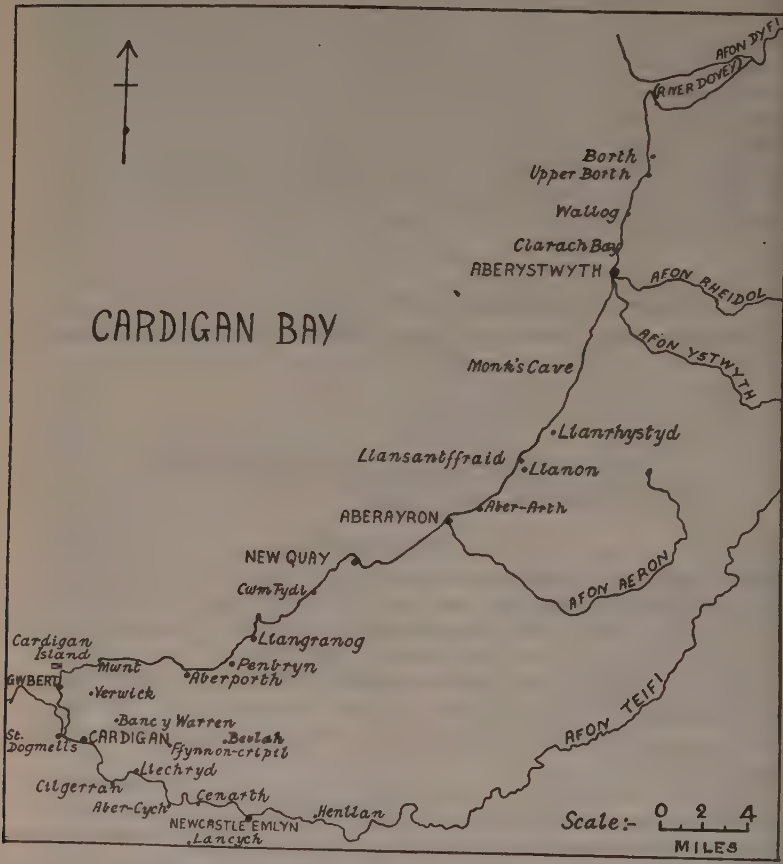

FIG. 1.—Sketch-map of Western Cardiganshire.

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[1] The figures in parentheses refer to the List of References at the end of the paper.

and brownish blue colour, with a sprinkling of subangular, ice-scratched pebbles". Among the pebbles, which Keeping recognized are Mountain Limestone, Old Red Sandstone, Coal Measure Sandstone, felsites, and greenstones. He concluded that the deposit had been formed by a glacier which originated "in the Caermarthenshire hills of South Wales, where the Upper Palaeozoic pebbles were obtained. Thence it streamed westwards, overriding the intervening watershed, and forcing its way down through the Teifi valley to the Irish Sea".

There is a reference to the drifts of Western Cardiganshire in a paper by Professor T. J. Jehu (3), in which he describes the deposits in the Cardigan Brickworks (previously mentioned by Keeping) and also refers to the sands and gravels at Banc y Warren, north-east of Cardigan. The sands and gravels, however, are not described as they lie outside the area discussed in his paper.

It is known that certain erratic boulders occur in North Cardiganshire which closely resemble the "felsites" in the Cader Idris and Aran country, north of the River Dovey. Keeping refers to these erratics (6, p. 254) and states that they, together with the boulders in the clay at Cardigan, are the only occurrences in the county of erratic blocks, the origin of which cannot be referred to the present valley systems.

II. DISTRIBUTION AND DESCRIPTION OF THE DRIFTS.

The greater part of the drift along the coast is the product of the Irish Sea ice, and the tripartite division of these deposits holds good in Cardiganshire, as in other parts of the Irish Sea Basin. It has been adopted, for example, for the drifts in Western Carnarvonshire and Northern Pembrokeshire by Professor T. J. Jehu (3 and 4), and is as follows:—

3. Upper Boulder-clay (youngest).
2. Sands and Gravels.
1. Lower Boulder-clay (oldest).

For purposes of description, it will be convenient to divide the coastal region into eight sections, and to consider the drifts there exposed and, finally to describe the drifts inland. The eight coast sections will be dealt with in the following order:—

1. The Teifi Estuary.
2. Traeth-y-Mwnt to Afon Soden.
3. New Quay.
4. Afon Drowy and Afon Cwinten.
5. Aberayron to Aber-Arth.
6. Morfa Mawr to Llanrhystyd.
7. Monk's Cave to Aberystwyth.
8. Clarach to Upper Borth.

1. *The Teifi Estuary.*—From a little distance south of Gwbert to a point on the east side of the estuary opposite St. Dogmells

(Pembrokeshire), there is a narrow strip of Lower Boulder-clay, which near Gwbert is at least 50 feet thick. It diminishes in thickness southwards where only a few feet of clay rest directly on solid rock.

The deposit is a massive, unstratified, blue, buff, or purple clay. It is extremely tough and when wet is as soft as plasticine, but when dry becomes harder and lighter in colour. The clay is so tough that it is often difficult to extract the scattered boulders which it contains. The boulders are generally well striated and polished, whilst the clay, although it is unstratified, tends to break up along irregular joint-planes (see Plate VIII, Fig. 1).

Erratics from the Lower Boulder-clay include a hornblende biotite granite (No. 1368),[1] which, in thin section, closely resembles the Galloway granites of South-West Scotland; three pebbles of coal, all of which are smooth and scratched, and numerous chalk flints. On the beach beneath the clay cliffs at Gwbert, there are large blocks of Carboniferous Limestone with *Lithostrotion* sp. and *Productus* spp., and boulders of a very coarse conglomerate containing pebbles of rhyolite and ash from 3 to 8 inches long. There can be little doubt that the boulders have been derived from the Lower Boulder-clay.

A few marine shells have been found in the clay, but they are mostly in a fragmentary condition and therefore difficult to identify. However, several forms of *Astarte* seem to be represented.

The Lower Boulder-clay is overlain, in places, by a few feet of Sands and Gravels, which are best exposed in a small pit on the hillside just north of Nant-y-ferwig. Here, the coarse gravels have a sandy matrix and are over 12 feet thick. The pebbles are often rounded, and apparently water-worn, but only occasionally bear any trace of striations. Many rock types foreign to the district are represented amongst the pebbles, and they include flints, limestones, and igneous rocks. One of the latter (No. 1363) may be compared very closely with the muscovite biotite granite of Creetown, Kirkcudbrightshire, whilst an olivine basalt (No. 1364) is similar to that of Megaberry, Moira, Co. Down. There is a small pocket of sands and gravels in the cliffs opposite the hotel at Gwbert, and in a stream near by, a pebble of the riebeckite microgranite of Ailsa Craig was found.

Above the Sands and Gravels, and often resting directly on the Lower Boulder-clay, there is a rubbly drift, which is a loamy or sandy clay containing scattered sub-angular and water-worn boulders, some of which have striated surfaces. This rubbly drift is never more than a few feet thick and has an irregular distribution. There are many erratics in the drift and one of them (No. 1366) resembles a markfieldite, and may possibly be from Yr Eifl, Carnarvonshire.

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[1] The numbers in parentheses, preceded by the abbreviation "No." refer to the collection of rock-slides in the Department of Geology, University College of Wales, Aberystwyth

2. *Traeth-y-Mwnt to Afon Soden.*—North-east of the Teifi Estuary, there are no glacial drifts exposed until one reaches Traeth-y-Mwnt, where a thick section of drift forms the eastern side of the small bay. Here the Lower Boulder-clay in cliff section is from 6 to 12 feet thick, and contains pebbles of Carboniferous Limestone with *Lithostrotion* cf. *martini* Edwards and Haime. On the beach there are boulders of this rock, with large radiating masses of *Lithostrotion*, which were probably derived from the Lower Boulder-clay. At the base of the cliff, the clay has yielded shell fragments, amongst which the following forms have been identified: *Cyprina islandica* (?) Linné, and *Astarte* spp.

Above the Lower Boulder-clay, there are about 40 feet of contorted gravels, which have yielded scattered shell fragments, generally too small to identify, but one almost complete specimen of *Purpura* was found.

North-eastwards, the next exposure of drift occurs at Aberporth. The Lower Boulder-clay occurs in both inlets at Aberporth, and in Traeth Dyffryn is not less than 50 feet thick, although it is not possible to determine the maximum thickness since the base is not seen, and the upper part of the cliff is obscured by landslides. On the eastern side of Traeth Dyffryn, the Lower Boulder-clay rests on about 18 inches of a roughly stratified deposit of rock rubble or "head", which consists of small angular fragments of local rock, closely packed and cemented by an earthy, ferruginous matrix. The Lower Boulder-clay has here yielded *Astarte elliptica* (?) Brown, and fragments of other marine shells.

In the westerly inlet at Aberporth, the Lower Boulder-clay is overlain by about 10 feet of Upper Boulder-clay, which is a much stonier deposit than the former, and consists of sub-angular, rounded, and often water-worn boulders in a loamy or sandy matrix. The Upper Boulder-clay is unstratified, and no order or arrangement can be detected, except in so far as certain intercalated streaks and lenticles of sand are horizontally disposed.

There is a small patch of gravel in the cliffs a quarter of a mile due east of Aberporth, and this is apparently the only occurrence of the intermediate groups of drifts in the neighbourhood. It may be mentioned that the Lower Boulder-clay extends inland for over a mile up the valley of a small stream which flows into Traeth Dyffryn.

East of Aberporth, coarse and fine gravels with sandy intercalations are overlain by rubbly drift at Traethsaith. Landslides obscure the junction and it is impossible to determine the thickness of the deposits, but the gravels are at least 40 feet thick at the north-eastern end of the bay. Still farther east, gravels occur again at Penbryn, but they are almost entirely concealed by blown sand.

Sands and gravels are again exposed at Traeth Bach, a mile south-west of Llangranog and at Llangranog itself.

Upper Boulder-clay occurs at several places between Llangranog and New Quay, as for example, at Trwyn Croi, Cwm Tydi, Castell Bach and around the mouth of the Afon Soden. At the last place, the deposit exhibits a rough horizontal stratification. The majority of the boulders in the Upper Boulder-clay can probably be referred to local rock types, but there are also many extra-Welsh erratics in the deposit, and from the drift at Cwm Tydi a pebble of the Ailsa Craig microgranite (No. 1362) was collected.

3. *New Quay.*—No more glacial deposits are seen until New Quay is reached, where both New Quay Bay and Little Quay Bay are backed by an almost unbroken line of boulder-clay cliffs. The boulder-clay forms a fairly high, uneven platform, in some places over a quarter of a mile wide, and extends up the valleys of the Afon Halen and the Afon Felen for three-quarters of a mile. The cliff sections are from 10 to 60 feet high, and the inland boundary approximates to the 150 foot contour, except in the two streams mentioned above, where it rises to over 300 feet O.D.

The Lower Boulder-clay is very well developed, and is exposed at the base of the cliffs along practically the whole length of the two bays. As seen in cliff section, it varies in thickness from 4 to 40 feet but, except near the Life-boat Station, the base is not seen, as the deposit disappears beneath the beach material, and at the headland separating the two bays, extends seawards for at least a quarter of a mile. The clay is generally a massive, homogeneous, unstratified deposit, containing scattered boulders. At the mouth of the Afon Felen the clay is roughly banded towards the base, but it passes upwards into a massive, buff-coloured loamy clay in which stones and boulders are extremely rare. It breaks up along vertical joint-planes so that the Felen flows through a small gorge with practically vertical walls on each side. In Little Quay Bay the clay is often distinctly mottled with large irregular blotches, which may be dark brown, bright yellow, or pale green, but, here, the cliff sections are very much overgrown and disturbed by landslides.

The Lower Boulder-clay is everywhere overlain directly by Upper Boulder-clay, except immediately to the east of the Afon Llethi, where intermediate Sands and Gravels separate the two boulder-clays. The Sands and Gravels are from 8 to 13 feet thick, and are the only definite example in the coastal region of the middle group of deposits occurring in association with both Lower and Upper Boulder-clays. The sands are brown and buff and strongly resemble ordinary marine sands, but they are much darker than those which occur in the south of the county. When traced laterally, they thin out rapidly. The succession of deposits at this point is shown in Fig. 2.

The Upper Boulder-clay at the western end of New Quay Bay is a fairly coherent deposit consisting mainly of boulders, often well striated, in a bluish grey clay matrix. Eastwards, it passes gradually into the normal, less coherent type of deposit, with a sandy matrix. Near the Life-boat Station, the Upper Boulder-clay overlaps the Lower, and comes to rest on a shattered surface of country rock (Aberystwyth Grits), and where the latter slopes down to and disappears beneath the beach there is a roughly stratified deposit of "head", which in turn underlies both boulder-clays and must have been formed previous to the deposition of the drifts. The Upper Boulder-clay varies in thickness from 6 to 40 feet.

There are few good exposures of the drifts inland. The best are found in the streams Llethi, Halen, and Felen. In the two latter, Lower Boulder-clay is found between the 200 and 300 foot contours, covered by a few feet of rubbly drift.

Many of the boulders in the drifts can be referred to local sedimentary types and the cone-in-cone nodules so characteristically developed in the Aberystwyth Grits are of frequent occurrence, but there are also many rocks in the clays which are quite foreign to the district. They include a pink quartzite (especially common in the Lower Boulder-clay), flints, fossiliferous limestones, and many igneous rock types.

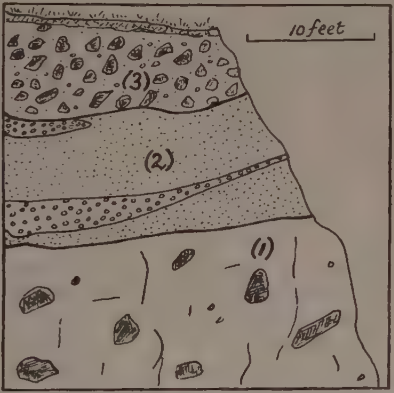


Fig. 2.—Sketch of cliff-section east of the Afon Llethi (New Quay), showing intermediate Sands and Gravels (2) separating the Lower (1) and Upper (3) Boulder-clays.

One of the limestones is a dark blue rock with a light, rusty-brown-weathering. A block of this limestone from the Lower Boulder-clay yielded the following fossils: *Trigonia sculpta* Lycett, *Ostrea* cf. *gibbosa* Sowerby, *Modiola* cf. *sowerbyana* d'Orbigny, *Rhynchonella* sp. (of the "*concinna*" group), and *Ostrea* spp. (acuminate forms, which Mr. J. Pringle informs me, resemble in size and shape *Ostrea acuminata* J. Sowerby, of the Inferior Oolite of Rodboro Hill, Avening). The fossil assemblage of this limestone indicates its age to be Inferior Oolite.

A boulder of dark grey limestone obtained from the Lower Boulder-clay in the Afon Halen, at nearly 200 feet O.D., yielded the following fossils: *Lima* (*Plagiostoma*) sp., *Pecten* (*Chlamys*) sp., *Pinna* sp., *Gryphaea* sp., *Modiola* sp., and stems of *Pentacrinus* sp. This assemblage suggests Lias rather than any higher formation.

Another limestone boulder is a sandy, calcareous rock which is full of small gasteropods possibly species of *Viviparus*.

Among the igneous rocks from the Lower Boulder-clay is one (No. 1360), which in thin section resembles the aplite of Twt Hill, Carnarvon, whilst from the Upper Boulder-clay has been recorded a pebble (No. 1359) which is similar to the Old Red Sandstone andesites of the Cheviot area.

Very small shell fragments have been extracted from the matrix of the Lower Boulder-clay but they are rare and too small to be identified.

4. *Afon Drowy and Afon Cwinten.*—There is a small pocket of rubbly Upper Boulder-clay in the cliffs on the south side of the mouth of the Afon Drowy but the most important section between New Quay and Aberayron occurs at the mouth of the Afon Cwinten. This latter stream has carved a channel through the glacial deposits, nearly 100 feet deep. Although for the most part the deposits are covered by vegetation, there are excellent exposures on the north-eastern side of the valley. The bulk of the deposits consists of sand and gravels, which are well stratified and in places show considerable contortion. The sands are light brown or yellow and, in places, argillaceous. They form the matrix of the gravels and sometimes occur as definite bands as much as 3 to 4 feet thick. The gravels are very variable in texture, ranging from coarse, gritty sands to pebble beds. The pebble beds on the side of the road, leading down to the beach, dip seawards at 40 to 50 degrees. These sands and gravels are from 75 to 100 feet thick, and are overlain by about 7 feet of Upper Boulder-clay. North and south of the stream, the Upper Boulder-clay overlaps the middle group and comes to rest directly on the solid rock.

To the north, the Upper Boulder-clay continues to cap the cliffs as far as Cwm Cilfforch and covers a narrow strip of Lower Boulder-clay immediately south of Pen y Gloyn, which is the south-western extremity of the area next described.

5. *Aberayron to Aber-Arth.*—Approaching Aberayron from the south, one immediately notices the low-lying coastal platform, which stretches up to and beyond Aber-Arth, a distance of nearly 3 miles, and on which stand both of the above-mentioned places. The average width of the platform is about a quarter of a mile and it slopes gently towards the sea from its inland boundary, which coincides approximately with the 100 foot contour line.

The Lower and Upper Boulder-clays build up this platform, but the best exposures are those seen in the cliff sections. Between Aberayron Harbour and Pen y Gloyn, the boulder-clay cliffs are over 50 feet high, whilst north of the River Arth, sections of the deposits attain a thickness of over 50 feet. However, elsewhere the sections are never more than 20 feet thick, and often the low cliffs are completely obscured and overridden by shingle.

The Lower Boulder-clay is exposed at the base of the cliffs along the greater part of the platform, and south of the harbour at Aberayron attains a thickness of 40 feet, but even so, the base is not exposed. It is everywhere overlain by Upper Boulder-clay, containing many water-worn boulders and possessing a characteristic sandy matrix, which causes the deposit to be readily disintegrated. In the stream at Aber-Arth the Upper Boulder-clay rests on a fairly level surface of solid rock which is probably part of the pre-glacial wave-cut platform.

Most of the boulders in the two boulder-clays are comparable with local rock types, but many, foreign to the district, also occur. The latter appear to have been derived mainly from the Lleyn Peninsula and the south-west of Scotland. Amongst those found in the Upper Boulder-clay are: a granite (No. 1338), similar to the Galloway granite, an Old Red Sandstone type of andesite (No. 1352) possibly from the Cheviot area; a kylite (No. 1354) from South Ayrshire; a microgranite (No. 1342) and a biotite granite (No. 1355), both probably from the Lleyn Peninsula; a grit pebble containing *Lingulella Davisi* M'Coy, presumably from North Wales, and a soda-granite (No. 1334) which resembles the Twt Hill rock, Carnarvon. From the Lower Boulder-clay come: a porphyrite (No. 1323) and a pyroxene-andesite (No. 1324) possibly from the south-west of Scotland, and in addition some Lleyn rocks.

The cliffs to the north of the Afon Arth present a complicated section, which for the sake of convenience will be dealt with at the end of the description of the coastal tract between Morfa Mawr and Llanrhystyd.

6. *Morfa Mawr to Llanrhystyd.* Equally as striking as the platform described above, is that which extends from Morfa Mawr up to and beyond Llanrhystyd, a distance of about 4 miles. The villages of Llanon and Llanrhystyd are located on this platform, which is generally below the 100 foot contour, and rather more than a quarter of a mile wide. A fairly even surface is maintained, except immediately north-east of Llanon, where mounds and ridges rise above 100 feet. The inland boundary, as of the other coastal strips, coincides, no doubt, with the old pre-glacial cliffs. The boulder-clay cliff sections are frequently obscured by shingle.

North of the Afon Wyre (the stream which passes through Llanrhystyd) the cliff sections are from 5 to 23 feet high and as they increase in height, two types of boulder-clay are exposed. The base of the cliff is composed of a stiff, dark blue or lead-coloured boulder-clay, containing angular and sub-angular boulders, which are generally well striated. The matrix is studded with small fragments of material similar to the boulders, and the whole could have been derived from the country rock in the immediate neighbourhood, or from rocks in the drainage areas of the Rivers Rheidol and Ystwyth.

Above this boulder-clay comes a drift similar to the former in many ways, but lighter in colour, rather less coherent and containing a few pebbles and boulders of distant origin. These boulders include flints, jaspers, schists, granophyres, etc., and some of them appear to have been derived from the Lleyn Peninsula and Anglesey. This boulder-clay passes upwards and laterally, in certain places, into a reddish brown, loamy clay, almost devoid of boulders, but containing shell fragments too small, however, for identification.

Farther south, the upper deposit alone is found, the lower disappearing some distance north of the Afon Wyre. Here, the upper deposit possesses a sandy matrix and towards the top is loose-grained and readily disintegrated. About 700 yards north of Llansantffraid, there are intercalations of yellow loamy clay with scattered boulders, and dark brown, false-bedded sands. The latter vary in thickness from mere streaks to bands 2 or 3 feet thick. These intercalations are important only for a distance of about 300 yards, as seen in cliff section.

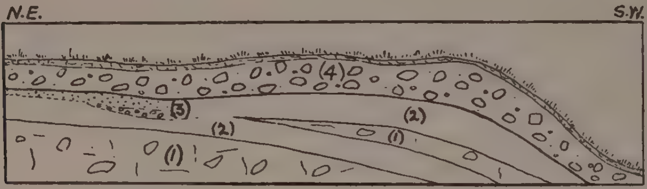


FIG. 3.—Diagrammatic sketch of the cliff-section north of Aber-Arth. (1) Lower Boulder-clay; (2) Local Welsh Boulder-clay with scattered, northern erratics; (3) sand and gravel; (4) Upper Boulder-clay. Length of section, 500 yards; height, 50 feet.

High cliffs of solid rock separate the Llanrhystyd platform from the Aberayron platform but it will be convenient to describe here the drifts in the northern part of the latter. Fig. 3 is a diagrammatic representation of the section in this locality. North of the Afon Arth the base of the cliffs is occupied by buff-coloured Lower Boulder-clay, which is as much as 25 feet thick, but ultimately disappears beneath the beach material. This Lower Boulder-clay is overlain by drift which is very similar to that which constitutes the greater part of the Llanrhystyd platform. It is a drift which closely resembles the strictly local Welsh Boulder-clay, but which contains some rocks foreign to the district. The two deposits merge gradually into one another, and the junction is only noticeable when the section is viewed from a considerable distance at low tide. The drift above the main mass of the Lower Boulder-clay

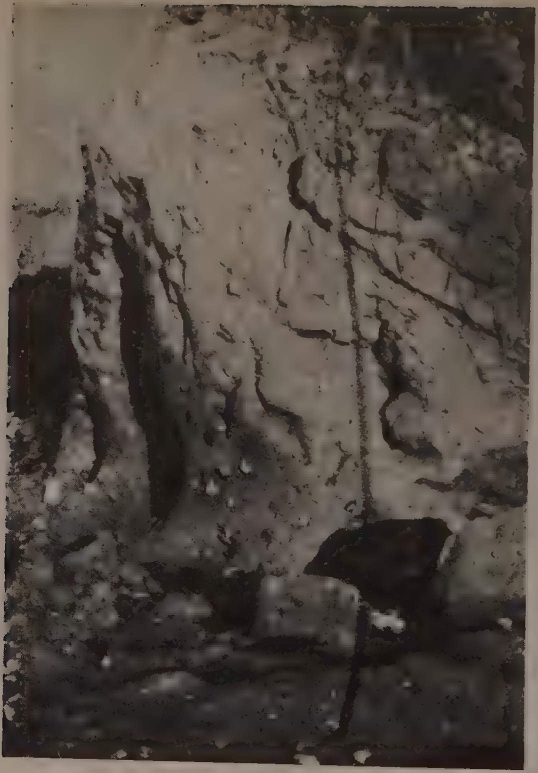


FIG. 1.

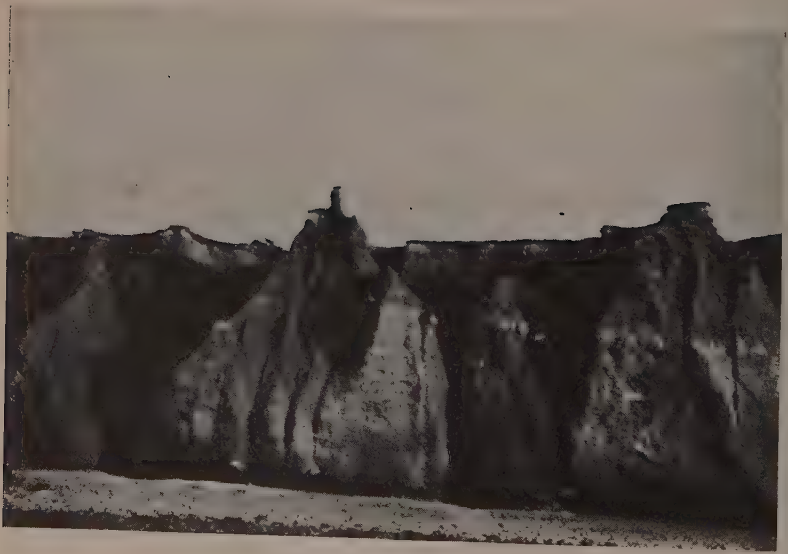


FIG. 2.

To face p. 215.]

is divided into two bands, each from 7 to 12 feet thick, by a wedge of massive, blue-grey Lower Boulder-clay. Above the drift at the northern end of the section, there is a band of fine sand, 3 to 4 feet thick, with about 18 inches of gravel at the base, but these sands and gravels die out rapidly southwards. It is possible that these sands and gravels represent the intermediate group of deposits found elsewhere. These deposits are overlain by 6 to 15 feet of Upper Boulder-clay, which is continued south of the Afon Arth as previously described. It may be mentioned that in this section, north of the Afon Arth, the boundaries of the various groups are obscured to some extent by detrital material washed down from above, and the cliffs themselves are mainly inaccessible, having been denuded into pillars and steep-sided gullies.

North-east of the mouth of the Afon Arth, the strip of glacial deposits gradually diminishes in width and disappears altogether in about half a mile. Where the Lower Boulder-clay has recently been removed, striae can be observed along the cliff face trending north-east and south-west.

7. *Monk's Cave to Aberystwyth.*—The stiff, lead-coloured boulder-clay which appears at the northern end of the Llanrhystyd platform is a continuation of the great mass of boulder-clay, which extends northwards from Monk's Cave for more than 2 miles. It here forms a narrow platform about 100 feet high at the edge of the cliff, and about 150 feet high at its inland boundary.

Keeping (6, p. 252) describes this boulder-clay as consisting of "a matrix of amorphous stiff blue clay crowded with small angular grains and shaly fragments. This paste is thickly studded with rocks of all sizes, from mere fragments to large masses several tons in weight. Most of the stones are subangular and well striated, a few are rounded, and others are unworn and angular. . . . All the rocks are of local origin". And, later on, he describes the features produced in the cliffs by denudation as follows: "small periodic streamlets . . . have cut their way back into the Glacial Clay, so as to form deep open gorges, with narrow, slit-like seaward openings, also fantastic ridges and pillars, in several cases leaving actual earth pillars, with capping stones, like the well-known examples in the Tyrol." Some of these features are seen in Plate VIII, Fig. 2, which also shows the rough banding sometimes exhibited by the clay.

The stiff clay passes upwards into a roughly stratified, reddish-brown sandy or loamy clay, packed full of boulders and pebbles, many of which are rounded.

There can be little doubt that the whole deposit is the product of the local Welsh ice, for a careful examination has failed to reveal any included rock fragments which are definitely not of local origin.

8. *Clarach to Upper Borth.*—North of Aberystwyth, along the coast, glacial deposits are preserved only at Clarach, Wallog, and in a small patch on the cliffs immediately south of the village of Borth.

South of the stream at Wallog, the cliffs of solid rock are fringed for 100 yards by boulder-clay, which is at least 50 feet thick. It is a brown deposit, consisting largely of pebbles and boulders in a sandy and gravelly matrix. The boulders are angular and sub-angular, but some are well rounded. There are bands and lenticles of stratified sand and gravel within the deposit. The cliffs between Wallog and Clarach Bay are capped by a thin, uneven layer of this boulder-clay, and at Clarach the deposit increases in thickness and once more forms the cliffs for a short distance, attaining a thickness of about 25 feet. The base of the cliff consists of dark blue boulder-clay, which passes upwards without any break into the looser, brown variety. On the south side of the bay about 10 feet of rubbly brown boulder-clay are overlain by a similar thickness of " head ".

Although practically all the boulders in this section of the coast can be matched with local rock types, there is one rock, at any rate, which comes from the country to the north of the River Dovey, and that is a " felsite " similar to that occurring at Cader Idris and in the Arans of Merionethshire.

Both north and south of the stream at Wallog and at the southern end of Clarach Bay, striated surfaces of Aberystwyth Grits may be seen where the boulder-clay has recently been removed by denudation. The general direction of the striae is parallel to the coast-line, that is, north and south.

The Deposits Inland.—The inland deposits of Cardiganshire have been described, in general, by Keeping (6) but he deals mainly with those due to the local Welsh ice and excludes, almost entirely, from his paper those deposits in the south-western part of the county which are not attributable to Welsh ice and with which this paper is, to a great extent, concerned. It will be sufficient to mention here that boulder-clays, similar to those last described, are frequently found in the valleys of the interior of the county, and in the coastal region as far south as New Quay. Some of the best sections in Western Cardiganshire are those in and about the valleys of the Rivers Rheidol and Ystwyth.

Those inland deposits, the origin of which may be ascribed to the Irish Sea ice, are confined to a relatively small area in the south-west of the county. The most extensively developed group is that of the intermediate Sands and Gravels, which are found resting either directly on solid rock or on the Lower Boulder-clay.

The best exposure of the Lower Boulder-clay occurs in the Cardigan Clay Pit described in detail by Professor Jehu (3, p. 65) and previously by Keeping (6, p. 254). Here, the clay is similar to that found along the Teifi Estuary and elsewhere. Many " foreign " boulders occur in the clay, as well as numerous scattered shell fragments, including various forms of *Astarte* (Professor Jehu's paper contains a list of shells found in this pit). The same clay is exposed in the Afon Mwldan, to the west and north of Crug Llwyn-llwyd, and in a small stream at Llwyn-llwyd Farm, where the clay is overlain by several feet of yellow sand. Cardigan obtains its water

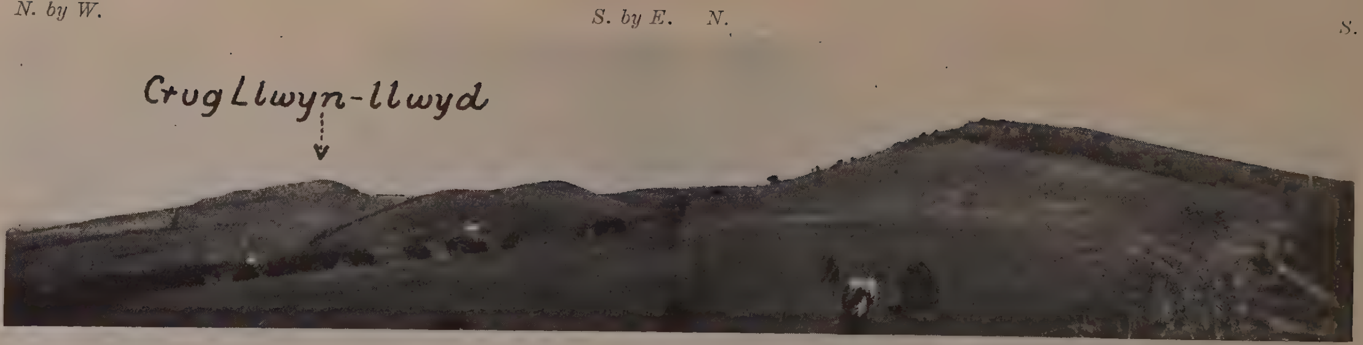
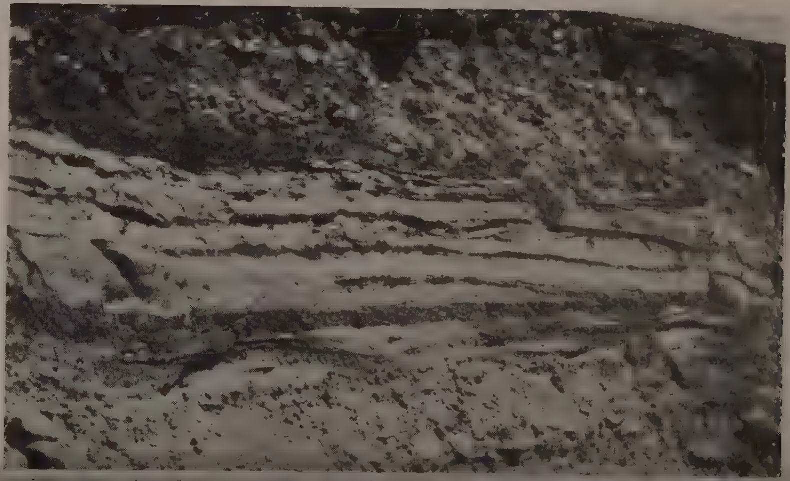


FIG. 1.



To face p. 217.]

supply from wells which penetrate the clay beneath the Sands and Gravels at Ffynnon Cedny and Ffynnon Pant-y-dwr, 2 miles north-east of the town. A boring for a well at Rhos-llyn (436 feet

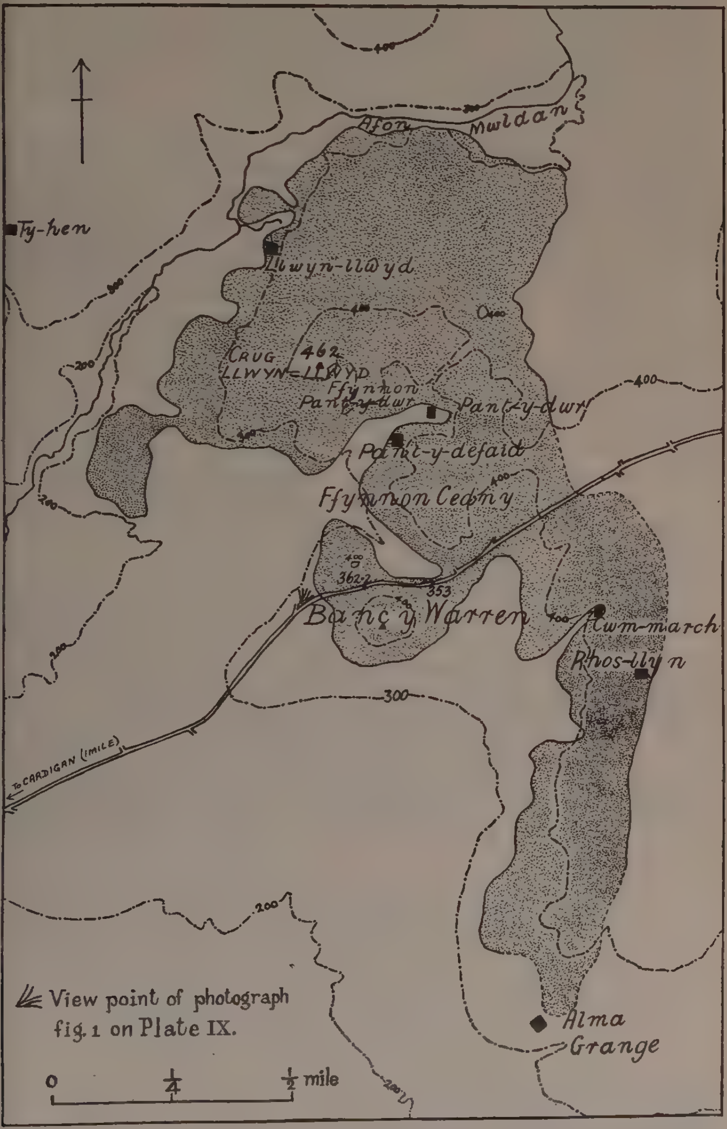


FIG. 4.—Map of the hills of Sands and Gravels (stippled area) north-east of Cardigan.

O.D.) half a mile east of Banc y Warren, passed through a few feet of dark blue clay (information supplied by a farmer who assisted in the sinking of the well). (See Fig. 4.)

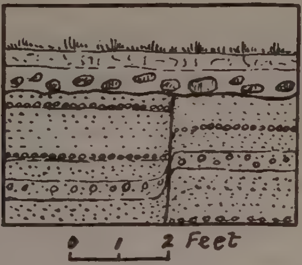
Blue-grey and buff clays are also seen in the Teifi valley at Aber-Cych, Cenarth, and Newcastle Emlyn. Here the clay occurs in the bottom of the valley beneath coarse gravels and is practically devoid of boulders. In its physical characters, it strongly resembles the Lower Boulder-clay, and additional reasons for supposing it to be the latter will be adduced later.

The intermediate Sands and Gravels are frequently exposed in the south-west of the county, where they often form distinctive topographical features. The main development, and that of greatest interest, forms the small group of hills to the north-east of Cardigan, the two highest of which are Banc y Warren (nearly 500 feet O.D.) and Crug Llwyn-llwyd (462 feet O.D.). (See Plate IX, Fig. 1.) The hills resemble a group of large sand-dunes, the longer axes of which range almost due north and south, with a long gentle slope to the north and a shorter, steeper slope to the south. These hills of sand and gravel have been mapped (see Fig. 4), but the boundaries mapped do not always define the exact limits of the deposits, for often they spread outwards as a thin mantle over an indefinite area. To the west and north-west, the hills are surrounded by Lower Boulder-clay, but to the east and south-east by solid rock (except for a short distance in the neighbourhood of Rhos-llyn). Similar hillocks, on a smaller scale occur in Pembrokeshire, as, for example, at Pen Crugiau Cemmaes (640 feet O.D.).

There are several good exposures in pits, which have been made in the hills, for sand and gravel. At the top of the small hill by the roadside, opposite Banc y Warren, there is a pit from 6 to 8 feet deep, and here are exposed very fine, pale yellow and coarser, brown sands, which resemble very closely ordinary marine sands. They are false-bedded and pass into fine and coarse gravels. The finer grained deposits yield innumerable shell fragments and occasionally almost complete specimens. From this pit the following have been identified: *Astarte elliptica* Brown, *A. compressa* Montague, *Turritella communis* Risso, and *Ostrea* sp. There are several small faults in the sand and gravel, each with a throw of a few inches only (see Fig. 5). Above the sand and gravel, there is a layer of water-worn boulders and pebbles, many of which are of distant origin. This layer does not appear to be affected by the faulting.

In an old pit on the western side of Banc y Warren, very fine, yellow sand is exposed and in association with it are water-worn pebbles, some of which, however, bear traces of striations. Similar sands and gravels occur in a pit at Pant-y-defaid, whilst an excellent section is to be seen in the gravel pit, east of Pant-y-dwr (see Fig. 4). This latter pit is about 16 feet deep, and is located in very coarse, false-bedded gravels or pebble beds, with an apparent dip of 30° to the west. The pebbles and boulders all appear to be water-worn; they nclude flints, and many different igneous types, one of which is coarse-grained granite with large, pink crystals of felspar. There re no fine sands in this pit, and no shell fragments have been found.

In the stream section at Llwyn-llwyd Farm a foot or two of golden and rests on Lower Boulder-clay, whilst at, and south of, Rhos-lyn there is a narrow strip of flat, marshy ground, separating the and on the west from the solid rock on the east for a distance of early half a mile. At Rhos-llyn the sand rests on a stiff, dark blue lay, and it seems probable that this strip of water-logged land epresents an outcrop of Lower Boulder-clay. Further, it is probable hat much of the ground between the southern tract of sand, which xtends from Cwm March to Alma Grange and Banc y Warren, and hat which extends southwards to Cardigan is also made up of ower Boulder-clay, although there are no exposures except in he Cardigan Clay Pit.



IG. 5.—Small fault in Sands and Gravels in mound, by roadside, opposite Banc y Warren. The mound occupies the right half of Fig. 1, Plate IX.

Mounds of sand and gravel occur at intervals between the area ust described and the coast, but owing to the lack of exposures and he fact that the deposits suddenly die out laterally or pass into a hin mantle of drift, it is difficult to map them accurately. One f the best sections of the sands and gravels is that seen at Verwick, n a mound on the hillside, west of the smithy. A recently excavated it shows the following generalized succession :—

		Ft.	in.
7.	Soil and rubbly drift	1–2	0
6.	Medium to coarse gravel with shells . . .		6
5.	Fine, pale-yellow, current-bedded sand with bands and wisps of fine gravel	2	0
4.	Coarse, brown sand (in west side of pit) . .	1	0
3.	Medium gravel with shells (ditto) . . .		9
2.	Coarse, brown current-bedded sand (ditto) . .	1	0
1.	Coarse gravels (with some big boulders) with shells in abundance. Base not seen	10	0

Part of the succession in this pit is shown in Plate IX, Fig. 2. he shells in this pit are mostly fragmentary and difficult to identify, ut the following appear to be represented : *Astarte compressa*

Montague, *A. sulcata* Da Costa, *A. elliptica* Brown, *Cyprina islandica* (?) Linné, *Cyprina* sp., *Turritella communis* Risso, and *Dentalium* (?). Some of the specimens of *Turritella communis* are remarkably well preserved, and several practically complete examples have been collected.

Coarse gravels are exposed in a small pit at Blaen Waen, three quarters of a mile south-east of Traeth-y-Mwnt at a height of 370 feet, whilst on the roadside, north of Ty'r-iet, there are fine brown and orange sands together with fine and coarse gravels.

Small mounds of gravel occur at Towyn, 300 yards east of the Gwbert Hotel and also by the roadside, half a mile due east of Cardigan, whilst near Ffynnon-cripil, 4 miles due south of Aberporth, and 5¼ miles due east of Cardigan, there is a little gravelly drift (with distant erratics) which overlies about 2 feet of rock rubble or " head ".

In and about the Teifi valley there are several good exposures of the Sands and Gravels. At the bend of the river, west of Llechryd and opposite Castle Malgwyn, a large pit in a mound of sand and gravel, reveals about 20 feet of coarse, bedded gravels, with layers of fine-grained, buff and orange sands from 1 to 2 feet thick. The sands and gravels are highly ferruginous in places and, apparently, are devoid of shells. They are overlain by about a foot of loamy, stony drift. Similar roughly-bedded gravels with thin lenticles of brown sand are exposed in a long gravel pit on the north side of the river at Aber-Cych. Here the gravels form a level stretch of ground resembling a river terrace. The boulders may be as much as 1 to 2 feet in diameter, and include many igneous and sedimentary rocks foreign to the district. The gravels are about 6 to 8 feet thick, and rest on a stiff, buff or blue-grey clay, generally devoid of boulders and pebbles, and bearing a strong resemblance to the Lower Boulder-clay. Continuing up-stream similar gravels are exposed just before Cenarth is reached, and again on the south side of the river, three-quarters of a mile east of Newcastle Emlyn. Here, a pit shows that the gravels are about 8 feet thick and well stratified. Many " foreign " boulders occur, but no shells have been found and the gravels rest on a dark blue or buff clay. At the western end of this outcrop of gravels, a quarry reveals some 20 feet of " head ".

Rock rubble or " head " is extensively developed in the south-west of the county. Several localities where it occurs have already been mentioned, and it is also exposed at Llechryd (behind Fron-hill), in the Nant Arberth (in the Cardigan-Llechryd road) and in a pit half a mile east of Beulah (seven miles east of Cardigan). In the latter place there are, associated with it, several " foreign " boulders which are well-striated.

Opposite Cardigan Island, the mainland slopes gently down to the sea, and smooth surfaces of rock frequently emerge from beneath the soil and drift. Professor Jehu (3, p. 62) states " Another very good example of a glaciated rock-surface is seen . . . at Gwbert, on the coast to the north of Cardigan. Here, emerging from beneath the drift again, a smooth and striated rock is seen—the direction of the striae being from a little west of north to a little east of south, showing that the ice must have come on to the land from the region of Cardigan Bay".

Erratics other than those in the Drifts.—There are many erratics, apart from those in the drifts, which are of interest in the south-western part of Cardiganshire. Some of them are marked on the 6-inch Ordnance Survey Maps as "stones". They occur in North Pembrokeshire even more commonly than in South-West Cardiganshire.

One of the most interesting is that which rests on a glaciated surface, north of the Gwbert Hotel and which measures 3 by 2 by 2 feet. It is a "green rock" or decomposed dolerite with porphyritic crystals of felspar and augite (No. 1369). It may possibly have been derived from the Southern Uplands of Scotland. East of Parc-y-rhos are several boulders of diorite and a hard green grit, both types foreign to the district. Erratics of a similar green grit are found in the small wood west of Tre-feredd-uchaf, one of them measuring 7 by 4½ by 3 feet. They are well smoothed and striated.

At Ty-hen, west-north-west of Crug Llwyn-llwyd, there is a well-striated boulder of green banded grit with coarse and fine streaks of chlorite. Resting on the glacial deposits at Traethsaith are several erratics (one measures 3 by 2 by 2 feet) of fine-grained gabbro and extremely tough green grit. The latter are similar to those mentioned above, and contain purple quartz grains and small pebbles of pink quartzite. A fine-grained gabbro, similar in hand specimen to that found at Traethsaith, occurs at Traeth Bach and measures 4 by 5 by 2½ feet.

A well-striated erratic (6 by 3½ by 3 feet) of coarse gabbro is situated just above Garnon's Mill on the north-eastern boundary of Pembrokeshire, and a similar gabbro known as the "Ogham Stone" occurs at St. Llawddog's Church, Cilgerran (Pembrokeshire). A beautifully striated erratic of dark blue slate may be examined near the railway between Cilgerran and Cardigan (1⅓ miles from Cilgerran), but this may possibly be a local rock.

III. SUMMARY AND CONCLUSIONS.

Of all the deposits described in this paper, the Lower Boulder-clay has the widest distribution. It is best seen along the eastern side of the Teifi Estuary and at intervals, along the coast, as far north as Aber-Arth. Inland, although rather rarely exposed, it seems to occupy a considerable area in the south-western part of the county, and probably extends as far east as Newcastle Emlyn. Reasons for supposing that the clay beneath the gravels at the latter place and at Cenarth and Aber-Cych is Lower Boulder-clay are: (1) its lithological similarity to that deposit, and (2) the fact that the Irish Sea ice must have passed over the Teifi valley in that neighbourhood, for gravels with distant erratics are found at a height of 400 feet O.D. at Lancych, about 4 miles south-west of Newcastle Emlyn, whilst at Beulah, 3 miles to the north, and a mile to the west of Newcastle Emlyn, there are " foreign " erratics at a height of over 500 feet O.D.

The Lower Boulder-clay is a very tough blue-grey or buff clay, generally containing sub-angular, beautifully striated boulders and pebbles. Many of the boulders are no doubt of local origin, and it would appear that the number of local boulders increases as the deposit is traced northwards. The deposit has a massive appearance and is never stratified, although it tends to break up along joint-planes.

Describing this clay in the Cardigan Clay Pit, Keeping (6, p. 255) states that it is the product of a " large glacier, which had its origin in the Caermarthenshire hills of South Wales ". This conclusion was due to the fact that he thought that many of the erratics in the clay had been derived from the Upper Palaeozoic rocks of that region. Whilst some of the rock types might have been derived from South Wales, they could equally have come from more northerly areas, and many of them have been identified as having been derived from the Lleyn Peninsula, and the south-west of Scotland, etc. The chalk-flints, for example, can only have come from the north-east of Ireland or from the bed of the Irish Sea. Moreover, Keeping apparently did not notice the marine shells in the clay. They prove conclusively that the ice which brought the deposit into the area must have travelled over a sea floor and in this particular case over the floor of the Irish Sea Basin.

The Lower Boulder-clay is regarded as having the characteristics of a true ground or bottom moraine and the striae in south-west Cardiganshire indicate a movement of the ice from west of north to east of south. It has been said that the *mer de glace*, which overwhelmed Anglesey and flowed down St. Georges Channel " invaded northern Pembrokeshire along its whole extent, and even encroached on Cardiganshire to the east " (3, p. 83). The present investigation shows that this encroachment was of considerable extent, and that the Irish Sea ice impinged on the Cardiganshire coast as far north as Aber-Arth and that to the south-west of New Quay it completely over-rode the land to some distance beyond the Teifi valley.

The boulders of Inferior Oolite and Lias (from the Lower Boulder-clay at New Quay) are of interest. The Inferior Oolite boulder could only have been derived from the west coast of Scotland, or the Inner Hebrides, whilst the Liassic boulder may have been derived from either the north-east of Ireland or the Inner Hebrides. In this connexion, it may be noted that a boulder of Middle Lias has been described at Ballintoy, North Ireland (10, pp. 324–5), whilst Middle and Upper Liassic fossils have been recorded in boulder-clay at 150 feet O.D., near the southern shore of Dublin Bay (9, p. 326). These erratics are ascribed to an Irish Channel or Scottish source of origin (1, p. 37). The presence of these Lias and Inferior Oolite erratics in such widely separated localities, finds a parallel in the even wider dispersal of the riebeckite microgranite of Ailsa Craig, a suggestive explanation of which has been given by the late Mr. Lamplugh (7, p. 390). He suggests that at the beginning of the Glacial Period, in the northern part of the Irish Sea, an ice-foot probably formed along the shores in winter and broke away in the summer into floes, which distributed their burden of rock fragments all over the floor of the Irish Sea, later, to be carried by the ice-sheet southwards into nearly every district where the marine shells were carried.

The Lower Boulder-clay is sometimes found resting upon an accumulation of rock rubble or "head", which separates the former from the solid rock beneath. This "head" is regarded as evidence of weathering under severe climatic conditions at the beginning of the Glacial Period and before the Lower Boulder-clay was deposited.

The Lower Boulder-clay is found up to a height of 436 feet in Cardiganshire (Rhos-llyn) whereas in Pembrokeshire it attains a height of nearly 600 feet, just to the south-west of Crugiau Cemmaes.

The Sands and Gravels.—The intermediate group of Sands and Gravels is most extensively developed in the south-western part of Cardiganshire, and is only occasionally seen along the coast. Every gradation from the finest sand to coarse gravel is exhibited by the group. The coarse gravels or pebble beds often resemble beach shingle, whilst the sands are similar to ordinary marine sands. Three points of interest may be mentioned: (1) they contain marine shells, (2) they are stratified, and (3) they often form definite topographical features.

The presence of marine shells shows that the sands and gravels once formed part of the loose material on the sea-bottom, which was later incorporated in the ice and transported in the same way as the Lower Boulder-clay.

The stratification and false-bedding exhibited by the deposits, points to the agency of running water as having been the main factor involved in their deposition after the transportation by the ice. There can be little doubt but that these sands and gravels are fluvio-glacial material, deposited in all probability at the margin of a retreating ice-sheet. From the retreating margin, streams of considerable velocity would normally issue and this would explain the false-bedding which is exhibited by even the coarsest gravels.

In South-West Cardiganshire and particularly to the east of Cardigan, the sands and gravels often form conspicuous mounds and hills, the longer axes of which trend approximately north and south. Professor Jehu does not consider that in Pembrokeshire, the sands and gravels form kames or eskers (5, p. 69). Professor J. W. Gregory has defined kames as "ridges or mounds of sand or gravel deposited by water on the margin of a melting ice-sheet" (2, p. 147). The mounds and ridges of sand and gravel in South-West Cardiganshire seem to fulfill the conditions of this definition.

The small faults, which are occasionally seen in these deposits (see p. 218) may be explained "by subsidences consequent on the melting of masses of ice included in the sands, as after the faults were formed powerful currents of water spread a sheet of coarse gravel over the ridge of sand". This statement is made by Professor J. W. Gregory (2, p. 118) in connexion with faults in an Irish esker, but seems to hold good in the present case, where a layer of boulders or coarse gravel overlies the mound of sand and gravel.

In the Teifi valley the sands and gravels have a roughly horizontal stratification and form level, shallow banks in the bottom of the valley, and occasionally small mounds on the valley sides. Some of the fluvio-glacial material in the valley bottom was, no doubt, deposited when the margin of the retreating ice-sheet was in the immediate neighbourhood; and for some time after the ice-sheet had retreated northwards, streams issuing from the margin would carry their load into the valley in the normal course of their drainage. The material thus brought down to or left in the valley would be subjected to the re-sorting action of the main stream, and be levelled to the condition in which it is now seen.

The Sands and Gravels are not nearly so well developed along the coast, and only at New Quay are they found separating the Lower and Upper Boulder-clays. Elsewhere they are generally found alone, or in association with the Upper Boulder-clay. It is possible that the intermittent developments along the coast are remnants of a former more widespread distribution, which was largely removed when the Upper Boulder-clay was laid down.

There are many distantly derived pebbles in the Sands and Gravels, and, as is to be expected, they have been transported from as many and as varied sources as those in the Lower Boulder-clay.

The Upper Boulder-clay.—The bulk of the Upper Boulder-clay occurs at New Quay, where it overlies both the Lower Boulder-clay and the intermediate Sands and Gravels, and also along the whole length of the Aberayron platform, where it rests directly on the lower group. It may possibly be developed to some extent along a part of the Llanrhystyd platform. Along the coast, south of New Quay, it only occurs in scattered patches and it is doubtful if the true Upper Boulder-clay is present inland. Covering the Sands and Gravels, inland, there is often a thin mantle of rubbly drift, and similar drift is scattered in patches throughout Northern Pembrokeshire. It is suggested, however, that this material represents the final débris left by the ice-sheet, which had deposited the Lower Boulder-clay and along the margin of which were deposited the Sands and Gravels.

The Upper Boulder-clay is a very stony deposit, and has comparatively little matrix which is generally of a sandy nature. The stones and boulders are sub-angular and often rounded and apparently water-worn, but striated boulders are not uncommon. As a result of the close packing of the boulders and the sandy nature of the matrix, the deposit is readily disintegrated and rapidly removed.

No shell remains have been found in the Upper Boulder-clay, unless the loamy deposit, which yields small shell fragments at Llanrhystyd, is referred to that group. Shells are conspicuously absent in the Upper Boulder-clay in North Pembrokeshire, whilst in Western Carnarvonshire they are rare and badly preserved.

Mr. Lamplugh accounts for the deposition of the Upper Boulder-clay by "a limited re-advance of the ice", which followed closely upon the local depositions of the stratified deposits (8, p. 548). The Upper Boulder-clay of the Isle of Man is confined to the low ground, and in Cardiganshire it appears to be restricted to the immediate neighbourhood of the coast. It seems, therefore, that the ice which deposited the Upper Boulder-clay did not override the land in the same way as that which carried and deposited the Lower Boulder-clay.

It has been stated that the Upper Boulder-clay has usually a sandy matrix and that it contains many pebbles which are apparently water-worn. Further, that along the coast where it is developed, the Sands and Gravels are only feebly represented. This suggests that the Sands and Gravels may have been very largely incorporated in the Upper Boulder-clay, when the latter was formed.

The Sands and Gravels are considered to represent a declining stage of glaciation, followed by a limited re-advance of the ice which deposited the Upper Boulder-clay. Dr. Jehu (4, p. 56) thinks it probable that the two boulder-clays are the products of ice-sheets of two glacial periods, separated by an inter-glacial epoch. Whether the Sands and Gravels represent an inter-glacial period, or merely a considerable oscillation of the Irish Sea *mer de glace* is a problem which cannot be solved by the observations so far made in Western Cardiganshire. The two boulder-clays can be accounted for by either theory. The Sands and Gravels certainly represent a temporary withdrawal of the ice in certain areas, but it is considered that they furnish no definite proof of a true inter-glacial period separating the periods of deposition of the Lower and Upper Boulder-clays.

The Local Welsh Boulder-clay.—Between Aberystwyth and Monk's Cave and for a short distance at the northern end of the Llanrhystyd platform, the boulder-clay is composed entirely of local rocks. This is the true local Welsh boulder-clay.

At Llanrhystyd, however, there is a deposit which closely resembles the local Welsh boulder-clay but is rather lighter in colour, and contains a few scattered pebbles which must have been derived originally from the more northerly parts of the Irish Sea Basin, for example, flints and schists. This boulder-clay forms practically the whole of the Llanrhystyd platform and is also found immediately above the Lower Boulder-clay at Aber-Arth. The great majority of the boulders in this deposit are of local origin, and it appears that it must be regarded as the product of the local Welsh ice which, however, picked up and incorporated within it a certain amount of Irish Sea material. The upper part of the deposit becomes rather gravelly and loose-textured and may possibly represent part of the Upper Boulder-clay along the Llanrhystyd platform.

Between Plynlimon and the coast, the country was probably, at one time, completely covered by ice. The general direction of movement of this ice was towards the west from the high ground around Plynlimon itself. This is inferred from striations and the distribution of erratics of Plynlimon rocks. However, along the Cardiganshire coast, observations of striae show that, here, the ice moved from north to south. It seems probable, therefore, that the southerly-moving Irish Sea ice acted as a barrier against the westerly-moving local Welsh ice, and that the latter was deflected into a north to south direction. There must have been a region, perhaps of considerable width, where the Irish Sea and Central Wales ice intermingled. In places, where the local Welsh ice was dominant, boulder-clay with local rock types was deposited, but farther south and west, Irish Sea material would become more important. The Cardiganshire coast trends obliquely to the general direction of movement of the Irish Sea ice, and, as has been mentioned above, Borth in the north is some 28 miles east of Gwbert in the south. Accordingly, as one might expect, it is in the northern areas of the coastal tract that purely local Welsh boulder-clay is found, whilst south-westwards we pass gradually into areas where the Irish Sea ice was the dominant factor in the deposition of drift.

North of Aberystwyth the boulder-clay is made up almost entirely of local rock types, but there are also pebbles and boulders of a volcanic rock, which is very similar to that found in the Cader Idris and Aran country of Merionethshire. Similar "felsite" erratics are known to occur inland in the extreme northern parts of Cardiganshire. This, coupled with other evidence shows that the northern parts of Cardiganshire were invaded by ice radiating southwards and south-westwards from the Merionethshire mountains. The interrelations of the Merionethshire and Cardiganshire ice sheets have not, as yet, however, been described.

In conclusion, I wish to record my indebtedness to Professor H. L. Hawkins and Mr. J. Pringle for considerable assistance in the identification of fossils and for suggestions as to the *provenance* of the fossiliferous limestones from the Lower Boulder-clay; to Professor A. H. Cox and Dr. G. W. Tyrrell for examining many of my rock slides and for valuable suggestions as to the *provenance* of certain rock types. The investigation was suggested to me by Professor W. J. Pugh, and my grateful thanks are due to him, and to Mr. J. I. Platt, for help and guidance in the field and also in the preparation of this paper.

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EXPLANATION OF PLATES VIII AND IX.

Plate VIII.

Fig.

1.—Base of the Lower Boulder-clay cliff, south of Gwbert.

2. Cliffs of local Welsh Boulder-clay, north of Monk's Cave, showing rough banding and features produced by denudation.

Plate IX.

1. Hills of Sands and Gravels, north-east of Cardigan. (View-point shown on Text-fig. 4.)

2. Top of pit (west side) in Sands and Gravels, west of the smithy, Verwick.

Further Observations on the Clay Pebble Bed of Ancon (Ecuador).

By George Sheppard, Ph.D.(Lond.), B.Sc., F.G.S., M.I.M.E.

IN connexion with the consideration of problems bearing upon the tectonics and the sedimentation of the Ancon area of Ecuador, a few additional observations can be made to those already presented by Messrs. C. Barrington Brown and R. A. Baldry.[1]

The clay pebble bed is of unique interest and, as far as the present writer is aware, it does not occur in any other part of Eucador except around Ancon, neither has it yet been recorded amongst the Tertiary formations of Peru.

On the other hand, it must be remembered that probably the oldest phases of the Tertiary—the Upper Eocene—occurring along the coast belt of this country are exposed only in the area under present consideration. Hence, whilst the material or deposits which present clay pebble features may exist elsewhere they are probably well covered by later deposits of Tertiary age, and are thus not available for examination in the usual field sections.

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[1] *Q.J.G.S.*, lxiii, 1925, p. 455.

In the paper quoted above the authors have suggested that the formation has been caused entirely by the overthrusting or over-riding of one mass of sediments over another; in other words "the clay pebble bed is the result of a great overthrust in soft sandstones and clays of Tertiary age".

With this observation to the effect that the clay pebble bed is a crush conglomerate of a thrust-plane, the present writer is only partially in agreement. There is no doubt that the clay pebble bed has been the medium for intense secondary compression and dislocation; it has been the more "competent" material for the expression of tectonic action, but it has not originated entirely as a result of these phenomena.

In the first place, the clay pebble bed is essentially a deposit (or a peculiar phase in the sedimentation) intercalated amongst the more normal Tertiary formations. Subsequent to its deposition and consolidation, however, it has been made the medium for the transmission and dispersion of the intense forces of compression which have affected the associated strata of this region, both above and below.

In brief, the clay pebble bed is a heterogeneous clay and sandy deposit containing :—

(1) Fragmental debris of an areno-argillaceous nature.
(2) Andean pebbles.
(3) Blocks of conglomerate.
(4) Rounded quartzite pebbles.
(5) Fossils (usually foraminifera).
(6) Clay pebbles.

The included rocks from an average sample collected in this locality have been identified megascopically as follow :—

(1) Porphyrites (Andean rocks of volcanic origin).
(2) Quartzite pebbles (light coloured to white).
(3) Black quartzite (veined).
(4) Greenish metamorphic rocks (probably slates).
(5) Indurated limestone.
(6) Altered sandstone and coarse grit.

With the possible exception of (2)—the quartzites—it is improbable that the other members of the series occur *in situ* either above or below the actual clay pebble bed, at any rate in such quantities as are now found in this formation. By this evidence alone it is difficult to appreciate the true significance of the "overthrusting" theory in order to account for the presence of the clay pebble bed.

It has been observed also by Mr. A. J. R. Murray and the present author that the base of the sandstone and shale stage immediately superimposing the clay pebble bed is frequently a grit containing quartzite pebbles, clay from the clay pebble bed, and foraminifera. This indicates a distinct unconformity between the two formations, and although later overthrusting may (and probably has in many cases) have taken place, it is obvious that the clay pebble bed is a true deposit, and has been laid down upon a local erosion surface of the earlier Tertiary strata.

Consideration must now be given to the various types of included material, as only by a study of these members can a fair idea be obtained as to the origin of the deposit itself.

The clay " pebbles " (from which the deposit receives its name), and the manner in which they are " set " in the clay country rock, form an index of great importance. Generally speaking, the pebbles are angular to sub-angular in shape, and although well rounded examples do occur (less than five per cent. however) the majority have sharp facets and have the appearance of broken shale fragments. A fact which has not been previously recorded, however, is that certain of the above pebbles are distinctly stratified by fine laminated sandstone. There is no doubt that at a later period of its history (i.e. in post-Oligocene times) the clay pebble bed, along with its associated sediments, became involved in a tectonic crustal movement, and this, in itself, would probably give rise to the " polished " appearance of the individual clay pebbles.

As a matter of fact, this glazed aspect of the pebbles is characteristic, and although the " glaze " may have been induced by compression (due to a fluxional movement of the matrix) it may, on the other hand, be due largely to the agency of mineral infiltration. The pebbles leave sharp casts in the matrix from which they can be easily extracted, but whether the casts are due fundamentally to compression (rock pressure) or are caused by secondary deposits of mineral matter (e.g. selenite) it is impossible as yet to express a definite opinion.

Other boulders, such as the rounded quartzites, etc., do not present polished surfaces other than those they had acquired prior to their incorporation in the clay pebble bed formation. In the case of the lenses of foraminifera which are found not infrequently in the clay pebble bed, it is difficult to understand how such delicate organisms could escape complete pulverization had that formation been caused primarily by the overriding of one block of strata over another. They could be preserved, however, in the case of a secondary deformation of the whole series. The presence of Andean volcanic rocks (invariably well rounded and obviously travelled-far) is a problem in itself which leads to conjecture on a large scale, but the fact that, in this part of Ecuador at any rate, such lithological types occur only in the clay pebble bed (excepting, of course, in the later Quaternary deposits) and do not occur in the associated sandstones and shales of the Tertiary formations, suggests that the clay pebble bed is a formation of an exceptional type, its component materials having been derived probably from considerable distances.

Dr. Bosworth[1] has described the peculiar and extensive breccia fans which are found in Peru, and suggests that these have been brought down from the mountain regions in the flood years which happen two or three times a century. The presence of similar rolled Andean pebbles in the Tertiary strata of Ecuador seems to indicate that even in Tertiary times cycles of excessive rainfall and flood may have occurred, during which huge quantities of detritus from the slopes of the Andes were probably transported to the lower levels of the " littoral ", where the Tertiary sediments were then being accumulated.

It is possible, indeed, that the clay pebble bed itself represents a phase of exceptional deposition due to abnormal climatic conditions.

Owing to the extreme paucity of organic remains in the Tertiary strata of Ecuador (with the exception of the foraminifera) the Eocene and Oligocene have not yet been subdivided with precision. The clay pebble bed is probably of late Eocene age, being associated with the upper Eocene deposits.

It is reasonable to assume, therefore, that the formation itself has been derived in the first instance from the denudation of a local Eocene land surface, and secondly, it has accumulated either in valley depressions or in lagoon-like estuaries.

At the moment, however, knowledge of the range and distribution of the Tertiary foraminifera in Ecuador is not sufficiently advanced for zonal work but, as referred to above, distinct lenses of these fossils occur sporadically in the clay pebble bed, having been probably washed into the deposit by the local erosion of a foraminiferal stratum. During the severity of a wet season, even at the present time, the denudation of a foraminifera-bearing sandstone gives rise literally to screes of these minute fossils, and these are transported and dispersed in a very short space of time.

The well-rounded quartzites, which are also characteristic of the clay pebble bed, form part of the same problem as that of the Andean porphyrites, etc., and may have been derived originally from the same source.

In connexion with the above the following observations made during the abnormal wet seasons of 1925 and 1926 will probably be relevant to the problem under consideration.

In rain-dissected areas, especially where the underlying formations consist largely of soft clay shales, the amount of detritus removed by gravitational action alone is enormous. During the continued process of " cutting-back " of the recognized valleys, the water-logged shales and sandstones slip to the lower levels of the ravine, and as, in a number of cases, the slope of the valley is steep, it can be seen that typical mud-flows will be formed.

An examination of the lithological nature and the constitution of a mud-flow is of great geological significance, as not only does it demonstrate clearly the great denudatory effect which an abnormal wet season has upon arid rock surfaces, but it throws considerable light upon certain curious and puzzling formations (e.g. the clay pebble bed) which are found in the Tertiary rocks of the present region.

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[1] T. O. Bosworth, *Geology and Palæontology of N.W. Peru*, 1922.

The record of the Tertiary rocks of this country indicates that most of the strata were deposited under varied conditions from deltaic, fluvial to lagoon, and there is unquestionable evidence that during the process of sedimentation of these beds exceptional floods and debouchements occurred over the then forming depositional area.

A typical mud stream of modern times (in South Ecuador) consists principally of the following materials :—

(1) Angular fragments of shale, rounded forms are rarely found owing to the nature of the "flow" of the matrix.

(2) Blocks of sandstone varying from small fragments to large masses which have been incorporated in the mud stream.

(3) Decomposed ferric concretions (obviously derived from the shales).

(4) Rounded quartzite pebbles.

(5) Thin streaks of foraminifera—the latter having been washed out from the sandstones of the country formations. The whole of the above principal "ingredients" are embedded in a thick paste of disintegrated clay shale and sandstone. The rounded pebbles (4) have been derived undoubtedly in this case from the degradation of the Quaternary sea-floors (tablazos) which at one time covered the greater part of the coastal terrain of this region.

It has been noticed repeatedly that isolated gravel patches occur commonly over the shale and sandstone outcrops of this district. These have been concentrated as a direct result of the solution and disintegration of the calcareous element of the tablazo (Quaternary) rock, and this process is rapid during periods of heavy rainfall. The gravel patches referred to above thus simulate beaches or "fans", but their origin, of course, is quite different.

The incorporation of rounded pebbles into a mud stream, therefore, presents no unusual difficulties as they naturally gravitate from the higher levels to the lower (i.e. near the plane of superposition of the Quaternary on the Tertiary) and thus become involved in the matrix of the flow during its respective stages of growth.

When a mud stream comes finally to rest it either occupies a valley depression or it extends beyond in form of a fan or a solid delta.

Its contact with the underlying formations is therefore irregular, but more usually the strata below have been slightly "planed" as a result of the flow-movement. In a geological sense, the structural section presented by the superposition of a consolidated mud stream upon faulted and disturbed strata is unique, and several false interpretations could be formulated upon the phenomenon.

The arguments brought forward by Mr. C. Barrington Brown and

Mr. R. A. Baldry in their detailed account of the origin of the clay pebble bed need a certain amount of amplification, their evidence derived from observations in the field is by no means conclusive and further it is not substantiated by additional data revealed by boreholes in this vicinity. Most of the difficulties of a stratigraphical nature can be explained by a true appreciation of the structure of these beds, and the present author certainly does not accept the greater part of the evidence which has been set forth previously in order to prove that the clay pebble bed is the result of a great overthrust.

Whilst it is true that the clay pebble bed does not usually reveal evidences of stratification, a certain alignment of materials is present in the matrix, these corresponding no doubt to the flowage of the original detritus prior to its consolidation. In this connexion it can be mentioned that observations have been made by the author in the Andes proper, and also along the coast belt during the recent abnormal wet season of 1925–6.

The above observations have confirmed the view that a recent mud-flow under certain conditions would simulate very closely the present appearance of what is now known as a clay pebble bed in the Tertiary. As has been pointed out in a previous paper,[1] the incorporation of exceptionally large boulders in a clay matrix is by no means impossible, especially when the medium of transportation is a slowly-moving mud stream.

The fact that a local conglomerate included as part of a clay pebble bed has been observed to be "teased" out and its constituent materials isolated in the matrix of the bed is meagre evidence to substantiate the great factor of overthrusting. This phenomenon, as will be explained below, has been induced by secondary tectonic movements, the latter having influenced most of the formations constituting the area under present consideration.

The slickensiding polish on the harder clay pebbles is indeed characteristic, but this feature again may be due to secondary movement induced after the initial consolidation of the formation.

In connexion with the high polish also on the quartz pebbles (recorded in the previous paper on this subject) it can be stated that, in the opinion of the present writer, the polish is not abnormal, and is certainly not greater than that which would have been imparted to the pebble naturally (as a rounded and water-worn fragment) prior to its incorporation in a clay pebble bed.

It can also be tentatively suggested that if the pressure of the clay matrix upon the surface of an included quartz boulder be great enough to cause a high polish it would be difficult—all other factors being equal—to account for the presence of the comparatively soft clay "pebbles" in the formation at all.

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[1] Sheppard, Geol. Mag., 1925, p. 368.

In all probability they would have been milled into an unrecognizable argillaceous powder and would not present, as the great majority do, angular contours.

The Clay Pebble Bed as an Index to Folding.—Recent investigations carried out in connexion with the geological sections penetrated by boreholes in the Ancon area have brought to light certain data which may have an important bearing upon our knowledge both of the origin of the clay pebble bed and also of its value as a tectonic factor in the elucidation of problems associated with the complicated folding found in this region.

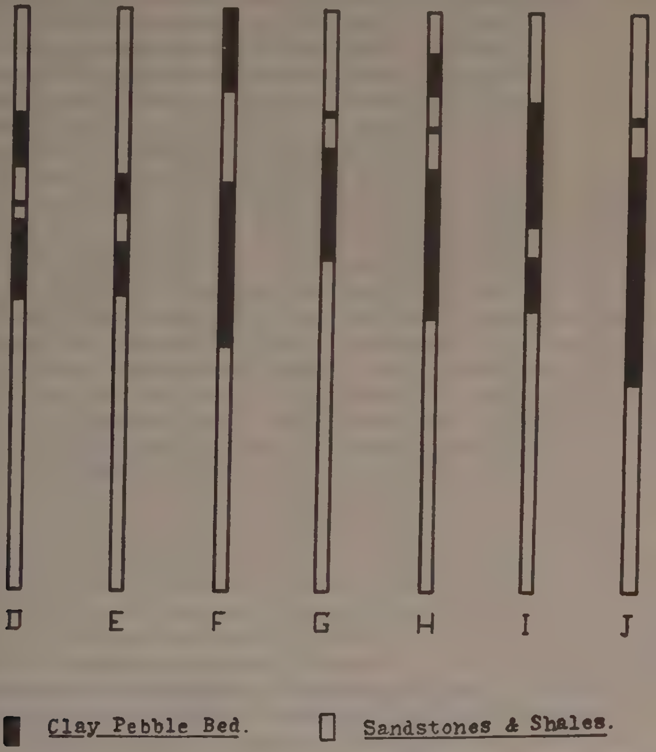

Fig. 1.—Sections penetrated by boreholes, D, E, F, G, H, I, J. Greater thicknesses of clay pebble bed are indicated where the strata are more steeply inclined, the more normal section being represented by D.

It has been noticed, for example, that in certain boreholes D and H (Fig. 1) two defined clay pebble bed horizons occur which are separated by a limited thickness of sandstones and shales. This latter interval, also, includes a thin layer—a few feet only—of clay pebble bed.

The borehole section thus presents in effect three clay pebble bed phases, the middle member being thin as compared with the upper and lower horizons of the same formation. Other boreholes (G and J) reveal the thin deposit at a comparatively shallow depth, then follow sandstones and shales, the latter being succeeded in depth by a further thickness of clay pebble bed.

Boreholes E, F and I present two phases of the clay pebble bed only (in varying thickness) and do not indicate the middle seam, as in the case of D and H. It is probable, however, that in the case of G and J the upper layer of clay pebble has been removed entirely by erosion. Assuming this, there are four boreholes (D, G, H and J) in which are present, theoretically, three clay pebble bed horizons, including the thin middle member.

It is the opinion of the author, however, deduced from the nature of both the upper and lower formations, that one clay pebble bed only occurs normally in the stratigraphical succession presented by the Tertiary group in the Ancon region.

The question at once arises, therefore, how it is possible to account for two or three phases of the same clay pebble deposit in the geological sections penetrated by the drill. This can only be answered by an appreciation of the general tectonics of the area, with special reference to the nature of the folds and consequent faults which occur. It has been recognized in the past that the geological structure of the Tertiary strata of this area has been extremely difficult to interpret, and indeed the structure along certain of the coast sections is so complicated that it is almost impossible to map the same with any degree of accuracy.

The highly disturbed nature of the formations is due to a repetition of tectonic manifestations, and it is of interest to note that a distinct zone of dislocation occurs in association with the clay pebble bed wherever the latter can be recognized as a surface outcrop. As has been described elsewhere[1] a deep isoclinal fold exists fundamentally in the strata of the Ancon area, and whilst this is of considerable importance in itself, other phases or cycles of deformation, resulting from secondary compression (and induced at a later geological period), have intensified the complexity of the structure to an advanced degree.

It is recognized, without question, that a series of tectonic forces (the majority of post-Tertiary age) operated in this region from a general easterly direction, and although the evidence presented by certain sections along the coast are certainly suggestive of rapid crustal movement, it is the opinion of the writer that the prevailing orogenic forces were slow in operation, and indeed may be in progress at the present time.

One factor, however, must not be overlooked in this connexion, this being the certainty of a much greater covering, or weight, of stratified deposits in this region at the commencement of tectonic activity. The amount of sedimentary material removed by subaërial denudation alone, since even the close of Quaternary times, has been enormous. In the main the Tertiary rocks of Southern Ecuador consist of an alternating series of sandstones and shales. As a consequence, the behaviour of these diverse lithological formations must be considered when individually under the influence of tectonic stress and strain. Sandstones are more "competent" to resist compression than are soft clay shales, hence whilst the arenaceous beds have a tendency to pulverize and to fracture into blocks, the shales are more or less adaptable to the prevailing forces; they form gliding planes for major dislocations in the superincumbent strata, and during this process all traces of original stratification are not infrequently obliterated.

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[1] Sheppard, *Economic Geology*, xxi, 1926, p. 70.

In the case of Ancon, the principal underlying structure can be described as distinctly unilateral, most of the forces have been exerted from an easterly direction, and apparently a zone of extreme shattering has been formed almost at right angles to this force, expressing itself in the region further to the west.

In addition, however, the structure of these beds has been further complicated and intensified by an overthrusting, or a "piling" of the overthrusted beds along the flank of the shattered zone. In brief, a series of roughly parallel recumbent folds (some of these having still further been resolved into isolated blocks of disturbed strata, thus resembling a number of reversed faults) has been forced from the south-east, possibly overlapping each other in a complex manner upon the eastern flank of the above mentioned major anticline.

It is well known that continuous or periodic tectonic forces acting principally from one direction will cause the formation of recumbent folds, the latter, at a later stage of growth, developing into reversed faults. As the pressure continues (assuming, of course, that the strain is not dispersed towards the west of the main fold), the different minor folds or overfolds are broken along their attenuated middle limbs, and the respective blocks are slipped over each other, thus producing a typical "imbricated" structure.

And, it is to be observed, the "slip" planes in the special case under consideration often include what are now recognized as phases of a clay pebble bed.

It will be noticed that if a borehole be drilled through a recumbent fold or its more advanced stage, the reversed fault block, it will pass through two major thicknesses of clay pebble bed (the two limbs of the fold) and also through a minor thickness which represents the attenuated middle limb, or drag plane, of the reversed fault.

Mention has already been made of examples illustrative of the above (Fig. 1, D, H) and, assuming that denudation has removed the upper limb of the fold, boreholes G and J are additional examples.

In certain cases, for instance (E, F, I), where apparently no middle limb is revealed during the process of drilling, it can be inferred that the recumbent fold has passed definitely into the stage of a reversed fault, and the clay pebble material has been so attenuated, or "kneaded", on the drag or slip plane that it has not been possible to recognize it in the borehole samples. From the above, therefore, it will be seen that in order to account for the presence of two (or possibly three) phases of the clay pebble bed in the same borehole no explanation other than that of the recumbent fold theory can be satisfactorily put forward.

Summary of Conclusions.

(1) The clay pebble bed of Ancon (Ecuador) is essentially a true deposit, probably formed, in the first place, by the denudation of an Eocene land surface under abnormal climatic conditions.

It has not been formed primarily by overthrusting or shearing, although these tectonic phenomena have undoubtedly affected the deposit at a later stage of its history.

(2) The clay pebble bed does not attain a thickness of more than three hundred feet, and it is included in about eighteen hundred feet of uniform clay shales and sandstones. The evidence collected from the drilling of boreholes suggests that recumbent folding has taken place in this area. No other explanation can satisfactorily account for the presence of two (or three) phases of the clay pebble bed in the same borehole. (Fig. 1.)

(3) Whilst stratification is not usually present in the clay pebble bed, a certain linear arrangement of the constituent materials has been detected which indicates a flowage in the deposit prior to consolidation. Later folding, however, has obliterated most of the evidences of original accumulation.

(4) Irregularities in the present attitude of the clay pebble bed and its associated strata (such as, for example, the upper limit of the clay pebble bed transgressing the bedding planes of the superincumbent strata, the upper limit apparently being a thrust plane from which minor thrusts branch into the upper block, the presence of transitional stages, etc., where the tearing away of the sole of the upper block is visible) can all be explained by an appreciation of the special tectonics of this area, which includes the theory of recumbent folding.

REVIEW.

A Review of the Genus Gisortia, with Descriptions of several Species. By E. Vredenburg. Mem. Geol. Surv. India (Palaeontologia Indica), n. ser., vol. vii, Mem. No. 3 (1927), pp. 78, pls. 32.

INDIAN palaeontology has suffered a severe set-back by the death of the gifted author of this memoir just as years of study had matured and a number of important monographs were in course of preparation by him. It is some slight consolation that this and several others had been sufficiently completed to allow of their posthumous publication. Although the present work is not primarily concerned with stratigraphy, it is, perhaps, rather a pity that editorial steps have not been taken to prevent giving further publicity to the views repeatedly expressed as to the existence of a big stratigraphical gap between the Ypresian and Lutetian stages, into which supposed gap a Lybian stage is inserted. Possibly, however, the recent work of Dr. W. L. F. Nuttall and Major L. M. Davies on the correlation of the Indian Tertiary formations appeared too late.

Gisortia, founded by Jousseaume in 1884 with the Eocene species "*Ovula*" *gisortiana* Passy as genotype, is one of the earliest genera of the Cypraeidae to appear; first met with in Albian rocks, it is particularly abundant in Upper Cretaceous and Eocene strata, some of the species attaining a gigantic size. At the present day the sole surviving representative is *G. umbilicata* (G. B. Sowerby), which occurs in Australasian waters.

The species described in greatest detail in the present monograph are those found in India and neighbouring regions, where they are of some value as stratigraphical indices. Unfortunately they are met with mainly as badly preserved internal casts, and one rather doubts if material of this nature is worthy of such profuse illustration. The memoir is, nevertheless, particularly valuable since it may stimulate other students to work of a similar nature; studies of this sort, in which the successive species and distribution of some individual genus are traced from horizon to horizon, have hitherto been far too rare in the field of molluscan palaeontology. The very thorough and systematic manner in which the author summarizes the literature is especially worthy of remark.

L. R. C.

REPORTS AND PROCEEDINGS.

Edinburgh Geological Society.

16th February, 1927.

" James Hutton: Father of Modern Geology, 1726–97." Bicentenary Address, by E. B. Bailey, M.C., B.A.

Hutton's dates may be compared with those of other representative founders of the age of science. Newton, 1642–1727, Linnaeus, 1707–78; Hutton, 1726–97; Watt, 1736–1819; Lavoisier, 1743–94; and Faraday, 1791–1867. His contemporaneity with Watt is noteworthy because his friend's steam engine almost certainly helped to mould his own idea of the earth as a heat engine. The function of heat in Hutton's earth was to consolidate sediment and to elevate it "to maintain vegetable and animal life". Volcanoes were for him safety valves. Hutton's contemporaneity with Lavoisier is significant for quite another reason. Hutton published his "Theory of the Earth" in the *Trans. Roy. Soc. Edinburgh* in 1788, and in book form in 1795. The French Revolution lasted from 1789–95, and removed Lavoisier's head in 1794. As Lyell points out, the bitterness with which Hutton's novel ideas were received was partly due to the political situation. Hutton's comprehensive contribution to geology is that the past should as far as possible be interpreted in the light of the present. His individual discoveries in regard to igneous intrusions, elevation, unconformity, erosional moulding of landscape, and geological time, are all too familiar to elaborate in this summary. His position, however, as the first glacialist has been strangely overlooked, and the credit passed on by accident to Playfair—who in most other respects gets far too little recognition. Hutton was often puzzled by the transport of boulders in his native land, but he did not conjure up Scottish glaciers to do the work. On the other hand, he proposed a former vast extension of existent Swiss glaciers to account for the distribution of Mont Blanc boulders which de Saussure had ascribed to deluges. "Let us now consider," he says, "the height of the Alps in general to have been much greater than it is at present; and this is a supposition of which we have no reason to suspect the fallacy; for the wasted summits of those mountains attest its truth. There would then have been immense valleys of ice sliding down in all directions towards the lower country, and carrying large blocks of granite to a great distance, where they would be variously deposited and many of them remain an object of admiration to after ages, conjecturing from whence or how they came."

16*th March*, 1927.

(1) "Further Problems in the Glacial Geology of North-east Scotland." By Alex. Bremner, M.A., D.Sc.

In the Survey Memoir on Sheets 86 (Huntly) and 96 (Banff) it was conclusively shown that the area dealt with has been subjected to at least two glaciations: (1) by ice moving from north-west to south-east and bringing with it erratics from the west and north-west, (2) by ice moving north and north-east towards the coast after the withdrawal of the earlier ice. Evidence was now adduced that northerly-moving ice was certainly not the latest occupant of most of the district; but that over practically all the ground in Sheets 96 and 97 (Fraserburgh) and in the eastern part of Sheet 86, the latest invader was ice moving—like the earliest ice—from the Moray Firth, while much of the rest of Sheet 86 was overspread by ice from the basin of the Spey. The existence of this ice-movement was established by (1) a study of direct overflow channels, marginal channels, and other phenomena of retreat, the position being taken that as the phenomena of retreat prove withdrawal of the latest ice-sheet towards west and north-west, so its advance must have been in the opposite direction; (2) the discovery of a boulder clay in Gallows Hill Pit, Cullen, which (*a*) rests on (disturbed) fluvio-glacial gravels deposited by the retreating ice of the northerly movement, and (*b*) contains erratics of western origin.

The drift section at Bay of Nigg, Aberdeen—a classic section since Dr. Jamieson's description of it in the *Quarterly Journal* for 1882—has yielded some surprising information. In the sands and gravels that underlie the Lower Grey Boulder Clay, a rhomb-porphyry boulder was found some years ago; and there systematic search has recently disclosed in situ five fragments of rocks characteristic of the Behelvie Igneous Complex. Moreover, on the foreshore opposite these lowest sands and gravels hundreds of boulders (including some of one to two tons in weight) from Belhelvie have been found, together with scarce Scandinavian erratics, one rhomb-porphyry and two laurvikites.

Belhelvie lies north-north-west of Bay of Nigg; and the presence of these boulders in, or presumably washed out of, the lowest part of the drift section suggested an early ice-movement from that quarter, hitherto unsuspected. This suggestion was confirmed by a study of erratics emanating from the eastern end of the Insch Igneous Complex at Berra Hill; a train of these has been traced to Dyce along a course parallel to a line from Belhelvie to Bay of Nigg.

These results raised a totally new set of problems of prime importance in the glacial history of Scotland.

(2) "A Cognate Xenolith in the riebeckite-trachyte of Mid Eildon Hill, Roxburghshire." By W. Manson and R. J. A. Eckford.

The xenolith is a riebeckite-aegerine-granite with micrographic structure. Detailed study of thin sections of the xenolith and of its contact with the trachyte lead to the conclusion that somewhere beneath the surface in the Eildon Hills neighbourhood there exists a mass of granite carrying riebeckite and aegerine. This granite was consolidated, but still very hot, at the time when part of it was broken off and carried upwards by the molten rock.

(3) "A section of Stratified Clays overlain by fluvio-glacial gravels at the Western End of the Railway Tunnel at Neidpath, Peebles." By W. Manson and R. J. A. Eckford.

The overflow from the glacial-lake in which these clays were formed seems to have been through the Neidpath hollow, commencing about the 650 or 700 foot contours. Continued erosion through the great melt-period of fluvio-glacial times seems to have lowered the level of the Neidpath valley to allow of its becoming a new and shorter course for the river. The pre-glacial course of the Tweed was the Cademuir-Hundleshope valley.

CORRESPONDENCE.

KEILORITES

(A new generic name for a Silurian Annelid from Australia).

Sir,—F. Chapman used *Trachyderma* J. Phillips,[1] for certain Polychaetous Annelids first described from the Silurian (Melbournian) strata in Victoria, Australia. This term is unfortunately preoccupied by P. A. Latreille[2] for a group of Coleoptera. The same name was used in the same year by J. L. C. Gravenhorst,[3] and in 1834 by A. F. A. Wiegmann.[4] I, therefore, propose *Keilorites*[5] gen. nov. with *Trachyderma crassituba*[6] Chapman, as genotype. The family Keiloritidae nov. then replaces Trachydermidae Chapman, for the Australian forms in question.

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[1] *Mem. Geol. Surv. Gt. Britain*, ii (1), 1848, p. 331.

[2] Règne Animal (Cuvier), ed. 2, v, 1829, p. 7. Col.

[3] *Ichneum Europ.*, i, 1829, Conspectus, p. 64, and iii, 1829, p. 283, Hym.

[4] *Herpetologia mexicana*, 1834.

[5] Keilor . . . a well-known Silurian locality in Victoria where A. James found beautifully preserved specimens. (*teste* Chapman, 1919, p. 317.)

[6] *Proc. R. S. Vict.*, xxii (N.S.), ii (April), 1910, pp. 103–4, pl. xxvii, figs. 1–4; pl. xxix, fig. 1; and ibid., xxxi (N.S.), ii, 1919, pp. 317–20, pl. xiii, fig. 3; pl. xiv, figs. 8, 9, and 12.